Factors Affecting Calf Crop

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Factors Affecting Calf Crop

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Preface

This book contains reports presented by speakers at the Beef Cattle Short Course on Factors Affecting the Calf Crop which was held at the University of Florida, May 6-8, 1965.

The Short Course was designed to bring together the available information on the many factors which affect the calf crop. Therefore, this book is a summary of what is presently known about this subject. It not only deals with information available in the United States but also draws on data from all parts of the world.

There are 29 contributors to the book. Many of them are national and international authorities in their respective fields. The chapters written by Dr. J. C. Bonsma, of the University of Pretoria in the Republic of South Africa, will especially be of interest. His work and findings are unique and should be a valuable reference.

It is hoped that this book will be helpful to cattlemen throughout the world. It should be a valuable reference for vocational agriculture teachers, county agents, colleges, universities, veterinarians, bankers, feed industry personnel, and all groups which deal with the beef cattle industry.

T. J. Cunha
A. C. Warnick
M. Koger

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I

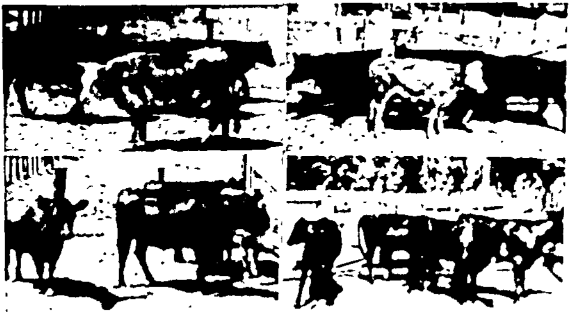
A. C. WARNICK

Introduction

The calving percentage in a beef herd is one of the greatest factors influencing success in the ranching operation. This calving percentage influences the economic returns and also the genetic improvement of the herd. Profit per calf can vary from $11.00 with a 100 per cent calf crop to a loss of $15.00 per calf with a 50 per cent calf crop based on a yearly cost of $60.00 to maintain a cow. By increasing the calf crop 5 per cent, from 75 to 80 per cent, the profit per calf would increase $5.00. The great impact on the cattle industry in the United States is seen by multiplying the number of beef cows (27,263,000) by $5.00 to give an increase of 136 million dollars if the calf crop could be increased by 5 per cent.

FIGURE 1. Protein deficiency in young beef bulls results in reproductive failure. Top—left to right—Control bull fed ration, 3 weeks on control ration after 252 days on protein deficient ration and protein deficient ration throughout. Bottom—Same bulls 99 days later. Weight of bulls: control, 1130 lbs., bull returned to control ration, 675 lbs.; and bull continuously fed a protein deficient ration, 311 lbs.

fall, temperature, solar radiation, and overall herd management such as time and length of the breeding season and time of weaning influence the calf crop. Also, genetic factors must be operating in calf crop variation since breed differences occur in Florida and elsewhere. It is the purpose of this text to give reports of various authors on ways of increasing the calf crop and, in turn, to increase ranch income.



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E. J. WARWICK

Reproductive Performance in World Regions

I am not sure there are many people in the world who can speak very authoritatively on this subject since adequate statistics are generally unavailable. I have managed to assemble some estimates which I hope will be of interest. For the most part, they have been assembled from scattered published sources and from people I know in various countries, or from Americans who have traveled or worked in other nations. I am extremely grateful to those who have helped me. To a large degree, the information to be quoted must be considered as educated guessing, since adequate data are not generally available for reproductive rates on a national basis. Thus, for the most part, the estimates given cannot be documented. It is quite possible that data may be available for some countries, but have not come to my attention. There are hundreds of reports on individual herds from various parts of the world. I have not attempted to make an exhaustive survey of these, but will refer to some of them.

First it can be said that, if we define optimum reproductive rate for cattle as being the production of a first calf at two to three years of age and another calf each twelve months thereafter, then sub-optimal performance is a worldwide problem. It is a considerably greater problem in some areas than in others and varies tremendously between herds within areas. We all know that reproductive failure can be due either to failure to drop a calf or to calf death prior to maturity or marketable age.

Starting with countries having climates more or less comparable to the temperate areas of the United States, it is estimated that the national average beef calf crop falls between 75 and 85

per cent in Canada. In two experiment station herds, calving percentages of 79 and 87 per cent, respectively, have been reported. It is estimated that on a national basis, Canadian dairy herds average a 65 to 75 per cent calf crop. Canadian artificial insemination units in 1962 and 1963 (over 900,000 cows each year) averaged first service conception rate based on 60-80 day non-returns at 68.4 per cent. In various provinces, it ranged from 66.0 to 72.2 per cent (Canada Department of Agriculture estimate).

Denmark is of special interest, since virtually 100 per cent of the cows are artificially inseminated and have been for several years. Too, it is a country with a generally high level of management. Virtually all cattle are dairy animals. There are a little over 1½ million cows in the country. The percentage of all cows becoming pregnant during the year has consistently been over 90 per cent, varying from 92.5 to 93.5 per cent during the years 1954-63. Per cent conception rate on first service has averaged about 60 per cent in recent years. Number of inseminations per conception has averaged about 1.68 (National Institute on Animal Husbandry — Denmark).

West Germany has between five and six million cows which are mostly of dairy and dual-purpose types. About 38 per cent are artificially inseminated. As a national average it is estimated that calf crops raised in 1962 and 1963 were 87.1 and 86.8 per cent, respectively. In artificial insemination, different parts of the country vary from about 58 to about 69 per cent conception on first service, from about 1.48 to about 1.55 in services per conception and from about 91.8 to 93.5 per cent pregnant after all

70 per cent in the Scottish Highlands. First calving there is often at four years of age.

In a survey of Charolais herds in France, an overall conception rate of 91 per cent and average calving intervals of 367 to 372 days were reported (Auriol *et al*, 1961).

On the basis of the above reports, it would appear that reproductive rates in northern Europe are generally among the highest in the world.

Information on southern Europe is much more limited. Studies of reproductive rates in individual herds have in some cases shown averages quite comparable to those of northern Europe. It is believed, however, that national averages are substantially lower.

Few data are available from Russia. This vast country varies tremendously in climatic and feed conditions. One visitor who had an opportunity to travel widely and observe agriculture over a wide range of conditions, has estimated average calf crop at not over 70 per cent.

In New Zealand, computations from published census data on beef herds permit estimates of per cent calf crop weaned ranging from 74.3 to 86.1 per cent in recent years. It is doubtful that year to year variation is this great, thus casting doubt on the validity of the estimates. A survey of 52 dairy herds in this country gave an estimated calving rate of 92 per cent. This may be high.

Australia is a huge country and conditions under which cattle are raised differ tremendously. In the temperate areas of New South Wales where rainfall is adequate, reproductive rates are apparently comparable to those of northern Europe or New Zealand.

In the low-rainfall areas, i.e., 10 to 20 inches, calf crops of 45 to 50 per cent raised are considered normal. A calf every 18 months is considered all that can be expected. Calf crops of 40 to 50 per cent are the rule in the tropic and subtropic areas of Australia. Very little supplementation is practiced in Australia. This is especially true in the tough cattle areas of Queensland, Northern Territory and Western Australia.

One report on the small cattle population of New Guinea indicated 60-70 per cent calf crop when bulls run with cows year round (Joshi *et al.*, 1957).

In the tropical areas of the world we can, without fear of contradiction, make the statement that low reproductive rates are of

transcendent importance to economical cattle production. Low conception rates and high death rates prior to a year of age are both of importance in most areas, but vary in their relative importance. In most nations we have better estimates of net calf crops raised than we do of birth and death rates. Thus, most of my remarks will relate to net calf crop.

All available estimates, including those made from slaughter (or extraction) rates, indicate net calf crops of from 30 to 50 per cent for all Central American countries and for all South American countries north of Chile, Argentina, and Uruguay. Their low national average reproductive rates are greatly exceeded by some herds in all countries. For example, at the research station at Turrialba, Costa Rica, dairy Criollas averaged only 1.4 services per conception. Similar results were observed in Venezuela.

Low net reproductive rates through this vast area are doubtless due to many causes, some of which are far from understood. Among the most common factors are: (1) Uneven distribution of rainfall, which in the absence of extensive programs for feed storage, result in cattle being on scanty forage of low quality for extended periods; (2) Use of breeds with built-in mechanisms to protect themselves (late puberty, suppression of estrus during lactation) from poor feed supplies and which fail to reproduce by temperate zone standards even when well fed; (3) Widespread disease situations which both reduce calving rates and increase calf death losses; and (4) Environmental temperatures with detrimental effects on reproduction phenomena for extended periods of the year. Speaking generally, reproduction rates are better in areas with more even distribution of rainfall throughout the year and in the highlands as compared to the lower, more tropical areas. Some breeds appear to reproduce more regularly than others. Among temperate zone dairy breeds, for example, the Jersey seems to have a superior reproductive rate when introduced into these areas.

Overall calf crops raised were estimated at approximately 60 per cent in both Uruguay and Argentina by one of my informants. Another source confirmed the 60 per cent figure for Argentina (based on considerable specific data) but gave Uruguay a lower figure—45 per cent or less. Within Argentina, considerable variation exists by region, with northern areas tending to raise calf crops of 50 per cent or less. This area is subtropical to tropical.

Calf crops in Chile are thought to average somewhat higher than in other South American countries—probably from 60 to 85 per cent in different regions.

I have very few detailed estimates on calving rates in Africa. However, from estimates given in the publication *Types and Breeds of African Cattle* (Joshi *et al.*, 1957), it appears that for much of the continent age at first calving ranges from 3 to 4½ years and that calving interval of the various breeds for the most part averages 15 to 24 months. If all calves lived, this would indicate calf crops of 50 to 80 per cent. Death losses tend to be high and net figures for much of the continent are probably considerably lower than this. As an example, one observer estimated that in much of Kenya and Uganda calf crop dropped may average 80 to 90 per cent. In a few of the better managed ranches, weaning percentages may approximate these figures. However, in the bulk of this area where East Coast Fever is a serious problem, death losses are high and calf crop weaned is probably not over 50 per cent.

In Egypt several studies of cattle and buffalo herds maintained by universities and experiment stations show calving intervals of 13 to 15 months. Records on one commercial buffalo herd showed an interval of 18 months (Ahmed and Tantawy, 1959 and El-Itriby and Asker, 1958).

While overall figures for Africa are low, reports of reproduction rates in individual experiment station herds are often quite good. For example, one study in the Congo reported calf crops of 92 to 100 per cent for different breeds (Maricz, 1961). A study in Ghana reported an average calf crop of 85 per cent for West African Shorthorns and only slightly lower rates for two other breeds (Montsma, 1963).

Thus, the overall conclusion would seem to be that average calf crop for most of this continent is low but that there are definite possibilities for improvement with enlightened management and disease control procedures.

Census data for the Republic of South Africa indicate a national average calf crop raised of 44 per cent. A number of surveys in this country, presumably among better managed herds, have indicated calving percentages of 61 to 89 for different dairy breeds and types of production. Similar figures for beef herds ranged from 52 to 77 per cent as averages of different regions of the country.

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Limited data from two beef research stations in the country show calving percentages of 60 to 63 at one and 81 to 92 at the other.

I have no estimates of overall national averages for southwest Africa, but a very interesting comparison of 12 breeds at the Omatjenne Experiment Station show average calf crops raised ranging from 73 to 88 per cent for different breeds.

The only estimates I have for the Middle East suggest an overall average calf crop of 30 to 40 per cent. In Israel the Arabs probably raise a calf crop of around 50 per cent while the Jewish farmers, using fairly intensive feeding and external parasite control programs, average about 65 per cent with their beef herds.

I have found no overall data on reproduction of cattle and water buffalo in southeastern Asia, but all observers report very low average rates. This may be due in part to the use of these animals for draft in the entire region and their veneration as religious symbols in much of India. Under these conditions high reproductive rates may be undesirable.

A number of studies, principally in herds maintained for dairy purposes at research stations and other government installations, indicate, however, that even where high reproductive rates are desired, they tend to be low (Singh and Choudhury, 1961; Kohli *et al.*, 1961; Singh and Desari, 1962). Most of these reports indicate average ages of first calving to be from 40 to 59 months and average calving intervals ranging from a low of 14 to 15 months up to as much as 21 months. The publication *Zebu Cattle of India and Pakistan* (Joshi and Phillips, 1953) gives figures for the various breeds which are in general compatible with the specific studies. For one breed, the Dhanni, an average calving interval of 33.8 months is indicated.

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TABLE 2.—CAUSES OF REPRODUCTIVE FAILURES*
(IN PERCENTAGE)

State	No.	Bred First 21 days of Breeding Season	Conceiving on First Service	Pregnant the First 21 days of Breeding Season	Not Showing Heat During Breeding Season	Diagnosed Pregnant	Calving	Calves Alive at:		
								Birth	2 Wks.	Weaning
Virginia	612	71	69	49	2	88	84	76	73	72
Louisiana	121	62	55	34	12	77	74	71	63	63
Nebraska	300	64	72	46	2	92	90	84	78	77

**Length of breeding season* was approximately 75 days in Virginia and Louisiana and 85 days in Nebraska.

TABLE 3.—CAUSES OF REPRODUCTIVE FAILURE IN COWS OF DIFFERENT AGES
(IN PERCENTAGE)

State	Age at Breeding	No.	Bred First 21 Days of Breeding Season	Conceiving on First Service	Pregnant First 21 Days of Breeding Season	Pregnant in Breeding Season	Not Showing Heat During Breeding Season
Virginia	2-3 yr. olds	127	66	64	42	81	6
	4 yr. and older	485	72	70	50	90	1
Louisiana	3-4 yr. olds	54	42	56	24	63	13
	5 yr. and older	67	78	55	43	84	1
Nebraska	3 yr. olds	71	55	78	43	84	0
	4 yr. and older	229	67	71	48	94	3

years. At Wyoming, calf crop varied from 74 to 94 per cent in the different years. Variation between years in the other states was also great. This illustrates that even though large differences in average calf crop are noted between the states, the differences within the state are as large or larger. If data were presented from different locations within each state it would be noted that wide differences in average calf crop exist in the same year at different locations within a state.

The causes of reproductive failure appear to be the same in all states. Only 71 per cent of the cows were in heat the first 21 days of the breeding season in Virginia, 62 per cent in Louisiana and 64 per cent in Nebraska (Table 2). Conception rate at first service was 69 per cent in Virginia, 55 per cent in Louisiana, and 72 per cent in Nebraska. Because of the small proportion of cows showing heat the first 21 days of the breeding season and the low conception rate at first service, the number of cows becoming pregnant during the first 21 days of the breeding season was less than 50 per cent in all 3 states. The low conception rate at first service and the proportion of cows in heat early in the breeding season also have a direct influence on the number of cows becoming pregnant during the breeding season. This varied from 92 per cent in Nebraska to 77 per cent in Louisiana.

Calf losses at or near birth was another important cause of reproductive failure. Calf losses at birth or before 2 weeks of age amounted to 11 per cent in Virginia and Louisiana, and 12 per cent in Nebraska (Table 2).

The three important causes of reproductive failure at all three locations were: (1) the number of cows in heat the first 21 days of the breeding season, (2) the number of cows conceiving at first service, and (3) the number of cows losing calves at or near birth.

Some other similarities of reproductive failure in these three widely separated states are of interest. Reproductive performance of young cows nursing calves at the three locations was lower than the reproductive performance of older cows nursing calves (Table 3). Fewer young cows showed heat the first 21 days of the breeding season (66 vs. 72 per cent in Virginia, 42 vs. 78 per cent in Louisiana, and 55 vs. 67 per cent in Nebraska). Consequently, fewer young cows became pregnant the first 21 days of the breeding season (42 vs. 50 per cent in Virginia, 24 vs. 43 per cent in Louisiana, and 43 vs. 48 per cent in Nebraska) and

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R. S. TEMPLE

Reproductive Performance in the South

The low reproductive rate of beef cattle in the South has received considerable attention from breeders and research workers, as it has been demonstrated that a calving percentage of less than 70 would lead to an uneconomical beef cattle operation under most circumstances. Several studies on reproduction in beef cattle have been conducted as a part of the Southern Regional Beef Cattle Breeding Project, S-10, since its initiation in 1948, and the results of these have been reported. These studies together with a survey of the reproductive status of the S-10 contributing herds furnish valuable information for beef cattle breeders.

fewer became pregnant in the breeding season (81 vs. 90 per cent in Virginia, 63 vs. 84 per cent in Louisiana, and 84 vs. 94 per cent in Nebraska). Thus, reproductive failure in young cows in all three states follows the same pattern but differs widely in magnitude.

The interval from calving to first heat is longer in young cows than in older cows at all three locations. Twenty-three per cent of the young cows in Virginia had an interval from calving to first heat of over 80 days compared to 16 per cent for older cows (Table 4). In Louisiana, 26 per cent of the young cows and 14 per cent of the older cows took longer than 80 days to return to heat after calving. In Nebraska, the proportion of cows taking over 80 days to return to heat was 43 per cent for young cows and 11 per cent for older cows. The same pattern between young and older cows is noticed with intervals over 90 days and over 100 days at all three locations.

TABLE 4.—INTERVAL FROM CALVING TO FIRST HEAT
(PERCENTAGE OF COWS IN HEAT)

		DAYS TO FIRST HEAT AFTER CALVING		
STATE	AGE OF COW	80 OR MORE	90 OR MORE	100 OR MORE
Virginia	2-3 yr. olds	23	18	15
	4 yr. and older	16	13	8
Louisiana	2-3 yr. olds	26	19	16
	4 yr. and older	14	9	6
Nebraska	3 yr. olds	43	30	15
	4 yr. and older	11	4	0

These observations show that the average calf crop differs quite markedly in different regions of the United States. However, the variation encountered within a region from year to year is as large or larger. The causes of reproductive failure in the different regions are remarkably similar and are (1) small number of cows in heat and bred the first 21 days of the breeding season, (2) small number of cows conceiving at first service, and (3) large losses occurring at or near birth. It would appear that methods which might increase calf crop in one region might also be effective in increasing calf crop in other regions.

calving percentages for each of these years are shown in Table 6. It should be noted that some cows are represented more than one year. The low weaning percentage in each of the four years exemplifies the seriousness of the low beef cattle reproduction rate in the Southeastern United States, as reported by Wiltbank *et al.*, 1961; Warnick *et al.*, 1960; Damon *et al.*, 1959; Cobb *et al.*, 1964; England *et al.*, 1963; and Koger *et al.*, 1962.

TABLE 6.—AVERAGES FOR YEAR AND MATING SYSTEM FOR THREE TRAITS EXPRESSED AS PERCENTAGES OF COWS IN THE HERD AT BREEDING, MINUS THOSE REMOVED FOR OTHER THAN REPRODUCTIVE CAUSES*

EFFECTS STUDIED	NUMBER IN HERD AT BREEDING	PERCENTAGE REMOVED FOR REPRODUCTIVE CAUSES	CALVING PERCENTAGE (BORN)	CALVING PERCENTAGE (WEANED)
Over-all				
Mean	19,388	7.9	77.3	69.1
Years				
1957	4,250	7.8	78.8	73.3
1958	4,681	7.5	74.6	69.8
1959	5,116	5.9	88.6	67.7
1960	5,341	10.5	67.3	66.5
Mating System				
Hand	1,554	5.8	88.0	79.8
Pasture	16,295	0.5	89.9	77.2
A. I.	1,539	17.4	54.1	50.4

*Effect of breed was removed, so that the percentages are as if the cattle were all one breed.

tus were removed from the herd prior to calving for causes other than reproduction. Since some of these cows could have fallen into one of two categories, open or pregnant, and, in many cases their conception status at the time of removal was not reported, it was assumed that their distribution into these two classifications was random and they were not included in this study. If the distribution of these "unknown" cows had not been at random in

TABLE 5.—TOTAL NUMBER OF COWS AND CALVES IN FOUR-YEAR REPRODUCTION SURVEY, S-10 HERDS, 1957-1961*

STATE	COWS†	CALVES
Alabama	814	564
Arkansas	1527	900
Florida	2715	1939
Georgia	1849	1486
Kentucky	158	138
Louisiana	1687	1059
Maryland	231	177
Mississippi	976	723
North Carolina	836	559
South Carolina	706	528
Tennessee	3849	2579
Texas	1685	1186
Virginia	2031	1053
West Virginia	324	237

*Includes all breeds and classes.
†This column actually represents "cow years", as many cows were used more than one year.

the open and pregnant categories, and if in fact a greater proportion of these cows had been pregnant than the ones actually included in the study, then the reported data would be biased in a downward direction. In an effort to eliminate any question as to how the cows that were removed for other than reproductive reasons would affect the data, the percentages reported have been calculated as percentages of the cows in the herd at breeding minus those removed for other than reproductive causes.

The factors included in the study of cow reproduction are: (1) percentage of cows removed for reproductive causes, (2) percentage of cows giving birth to calves, both dead and alive, and (3) percentage of cows weaning calves (this does not include calves sold before weaning). The number of cows in the four-year study, the percentage removed for reproductive causes, and the

calving percentages for each of these years are shown in Table 6. It should be noted that some cows are represented more than one year. The low weaning percentage in each of the four years exemplifies the seriousness of the low beef cattle reproduction rate in the Southeastern United States, as reported by Wiltbank *et al.*, 1961; Warnick *et al.*, 1960; Damon *et al.*, 1959; Cobb *et al.*, 1964; England *et al.*, 1963; and Koger *et al.*, 1962.

TABLE 6.—AVERAGES FOR YEAR AND MATING SYSTEM FOR THREE TRAITS EXPRESSED AS PERCENTAGES OF COWS IN THE HERD AT BREEDING, MINUS THOSE REMOVED FOR OTHER THAN REPRODUCTIVE CAUSES*

EFFECTS STUDIED	NUMBER IN HERD AT BREEDING	PERCENTAGE REMOVED FOR REPRODUCTIVE CAUSES	CALVING PERCENTAGE (BORN)	CALVING PERCENTAGE (WEANED)
Over-all				
Mean	19,388	7.9	77.3	69.1
Years				
1957	4,250	7.8	78.8	73.3
1958	4,681	7.5	74.6	69.8
1959	5,116	5.9	88.6	67.7
1960	5,341	10.5	67.3	66.5
Mating System				
Hand	1,554	5.8	88.0	79.8
Pasture	16,295	0.5	89.9	77.2
A. I.	1,539	17.4	54.1	50.4

*Effect of breed was removed, so that the percentages are as if the cattle were all one breed.

yearlings and 57.1 per cent when used as two-year-olds. Twelve bulls used for natural service at the Front Royal station from 1956 to 1958, and for artificial insemination from 1950-1960, had conception rates of 78.5 per cent and 50.4 per cent from natural and artificial breeding, respectively. Conception rates of cows bred twice during a single heat period were not different from those of cows bred only once. Lactating cows were not found in estrus as early as dry cows and yearlings, but had a distinctly higher conception rate.

In the survey, some states had higher calving percentages for cows nursing a calf when bred than for cows bred when dry, while other stations had the reverse situation, as indicated in Table 7. Eleven states culled more cows bred when dry for reproductive reasons than those bred when nursing a calf, while two states culled more cows bred when wet than those bred when dry, and one state culled an approximately equal percentage of each type. The culling practice in most states of removing more of the cows bred when dry for reproductive failure than those bred when wet, undoubtedly, has an effect on the fact that in many of these same states, cows bred when wet gave birth to and weaned a larger number of calves. In only four states, Florida, Louisiana, Kentucky, and West Virginia, cows bred when dry gave birth to and weaned a larger number of calves than those bred when nursing a calf. The percentage of calves born in each lactation status was about equal in Virginia, but this state showed a slight advantage in weaning percentage for cows bred when wet.

Workers in Louisiana (England *et al.*, 1963) and in Florida (Koger *et al.*, 1962) have reported higher conception rates in non-lactating cows than in dry cows, but both studies indicated that this difference was not consistent in all breeds. The Florida study also indicated that cows bred when dry had similar weaning percentages on different types of pastures, while those bred when wet had a marked advantage in weaning percentage for improved pastures, in comparison to native ranges.

Calving percentages for the different ages of dam represented in the S-10 survey was similar in each of the four years. However, cows bred when dry surpassed those bred when wet for the two and four-year-old age groups in both per cent born and per cent weaned, while those bred when wet excelled in these factors in the three-year-old group, as shown in Table 8. Wiltbank and Harvey (1963) reported weaning percentages of 77.1

TABLE 7.—AVERAGES FOR THREE REPRODUCTIVE TRAITS EXPRESSED AS PERCENTAGES OF COWS IN THE HERD AT BREEDING MINUS THOSE REMOVED FOR OTHER THAN REPRODUCTIVE CAUSES FOR STATE AND LACTATION STATUS*

EFFECTS STUDIED	NUMBER IN HERD AT BREEDING	PERCENTAGE REMOVED FOR REPRODUCTIVE CAUSES	CALVING PERCENTAGE (BORN)	CALVING PERCENTAGE (WEANED)
Over-all mean	19,388	7.9	77.3	69.1
Alabama				
Wet	545	0.0	71.4	66.0
Dry	269	10.1	68.6	60.2
Arkansas				
Wet	768	6.0	67.8	65.4
Dry	759	15.9	60.7	55.7
Georgia				
Wet	1,158	5.8	83.0	79.6
Dry	691	12.4	77.2	68.5
Florida				
Wet	1,859	13.7	72.1	69.3
Dry	856	13.4	80.5	75.8
Kentucky				
Wet	117	6.2	73.6	69.5
Dry	41	0.0	100.0	100.0
Louisiana				
Wet	982	10.1	67.7	60.3
Dry	705	13.1	73.2	60.7
Maryland				
Wet	177	2.4	85.7	81.8
Dry	54	13.9	70.5	58.2
Mississippi				
Wet	663	7.5	78.6	72.1
Dry	313	9.5	71.6	64.7
North Carolina				
Wet	556	6.8	83.7	74.0
Dry	280	13.9	81.9	66.2
South Carolina				
Wet	441	1.8	76.6	72.9
Dry	265	7.5	71.4	62.2
Tennessee				
Wet	2,466	10.0	77.7	69.5
Dry	1,383	16.3	68.7	55.9
Texas				
Wet	1,121	3.4	82.7	76.7
Dry	564	7.3	75.5	65.7
Virginia				
Wet	1,087	1.8	76.9	63.9
Dry	944	3.5	77.6	60.2
West Virginia				
Wet	288	4.9	88.2	76.4
Dry	36	3.0	96.0	81.0

*Effect of breed was removed, so that percentages are as if the cattle were all of one breed.

and 63.2 per cent, respectively, for first-calf two-year-old and three-year-old Brangus heifers which dropped live calves. They also reported calving percentages of 58.2 for three- and four-year-old cows bred when wet and 79.5 for a similar group bred when dry. In this same study, five- to ten-year-old cows bred when wet had a calving percentage of 73.4, as compared to 82.1 per cent for a similar group bred when dry, and cows eleven years old and older, bred when wet, had a calving per cent of 63.4, while those bred when dry had 76.9 per cent. Koger *et al.*

TABLE 8.—AVERAGES FOR THREE REPRODUCTIVE TRAITS EXPRESSED AS PERCENTAGE OF COWS IN THE HERD AT BREEDING MINUS THOSE REMOVED FOR OTHER THAN REPRODUCTIVE CAUSES, FOR AGE OF DAM AT BREEDING AND LACTATION STATUS*

EFFECTS STUDIED	NUMBER IN HERD AT BREEDING	PERCENTAGE REMOVED FOR REPRODUCTIVE CAUSES	CALVING PERCENTAGE (BORN)	CALVING PERCENTAGE (WEANED)
Over-all mean	19,388	7.9	77.3	69.1
Two-year-olds				
Wet	806	7.0	71.5	66.5
Dry	4,329	7.6	78.3	72.3
Three-year-olds				
Wet	2,337	7.4	82.5	76.1
Dry	948	7.1	77.9	67.3
Four-year-olds and older				
Wet	9,085	15.1	75.0	64.0
Dry	1,883	12.8	78.3	70.9

*Effect of breed was removed so that the percentages are as if the cattle were all one breed.

(1962) reported that age of cow had a pronounced effect in both classifications, with the lowest reproduction occurring in the two- and three-year-old heifers, increasing to a peak at six or seven years, and remaining nearly constant to 18 years of age for those bred when dry, while declining slightly for those in the group bred when wet. However, lowered reproduction of young cows was more pronounced in lactating females. A study by Meade *et al.* (1961) indicated that reproduction rates reached a peak in Brahman cows at approximately six years of age and declined somewhat thereafter. In a study including Angus, Hereford, and Shorthorns at the Front Royal station and Brahman, Brahman-Angus, and Africander-Angus, based on crossbred foundations,

at the Jeanerette station (Wiltbank *et al.*, 1961), the proportion of heifers and wet cows which conceived at first service was similar at Front Royal, but the conception rate of cows bred when dry was lower. At the Jeanerette station, the conception rate of the Brahman-Angus was quite low in first-service conceptions.

EFFECT OF BREED

In reporting differences in reproduction rates among breeds at the Jeanerette station, DeRouen *et al.* (1963) indicated conception rates of 66 per cent for Sindhi cattle, 80 per cent for Brahman, and 82 per cent for Angus. The Angus raised 92 per cent of their calves to weaning, while the Sindhi and Brahman raised 80 and 71 per cent, respectively. Six per cent of the Sindhi cows refused their calves at birth or shortly thereafter. Wiltbank *et al.* (1961) reported considerably higher conception rates for Angus, Hereford, and Shorthorn cattle at the Front Royal station, in comparison to cattle containing Brahman breeding—Brahman-Angus, Africander-Angus, and Brahman—at the Jeanerette station.

Since data involved in the four-year survey included 98 breed and breed-cross groups, some of which were located at only one station, no attempt was made to estimate the effects on reproduction of all these breeds. However, the reproduction data on six straightbred groups, Angus, Brahman, Brangus, Hereford, Santa Gertrudis, and Shorthorn, were studied for the effect of breed group and lactation status, as shown in Table 9.

Approximately 9 per cent of all cows studied were culled for reproductive reasons. A slightly larger proportion of dry cows was culled in the Angus, Brahman, Hereford, and Shorthorn breeds, and a slightly larger number of wet cows was culled in the Brangus and Santa Gertrudis breeds.

The Angus and Hereford cows bred when wet exceeded those bred when dry in both the per cent of calves born and calves weaned; while in the other breeds, cows bred when dry had the higher calving per cent, with the exception of the Shorthorns in which cows bred when dry excelled in calves born and those bred when wet excelled in calves weaned. This difference in the Shorthorn breed group was small in comparison to the differences between these groups in the other breeds. The cows bred

when wet exceeded those bred when dry by approximately 9 per cent in the Angus and 8 per cent in the Herefords in weaning per cent; while the cows bred when dry exceeded the cows bred when wet by approximately 4 per cent in the Brahman breed, 4 per cent in the Brangus, and 15 per cent in the Santa Gertrudis, which indicated that in cows having some Brahman breeding the cows bred when dry tended to have a higher conception rate and, consequently, weaned more calves than cows bred when wet. The opposite of this was true for cows of British breeding.

TABLE 9.—AVERAGES FOR THREE REPRODUCTIVE TRAITS EXPRESSED AS PERCENTAGES OF COWS IN THE HERD AT BREEDING MINUS THOSE REMOVED FOR OTHER THAN REPRODUCTIVE CAUSES, FOR BREED AND LACTATION STATUS*

EFFECTS STUDIED	NUMBER IN HERD AT BREEDING	PERCENTAGE REMOVED FOR REPRODUCTIVE CAUSES	CALVING PERCENTAGE (BORN)	CALVING PERCENTAGE (WEANED)
Over-all mean	15,201	8.7	76.5	67.8
Breed x Lactation				
Angus				
Wet	3,236	8.4	81.8	75.7
Dry	2,145	9.3	75.5	66.7
Brahman				
Wet	397	8.2	71.1	57.1
Dry	255	8.7	79.7	61.4
Brangus				
Wet	383	9.3	72.5	65.4
Dry	202	8.9	79.5	69.3
Hereford				
Wet	4,659	8.1	82.7	77.3
Dry	2,442	8.8	77.7	69.6
Santa Gertrudis				
Wet	205	9.0	68.9	63.6
Dry	154	6.4	81.3	78.5
Shorthorn				
Wet	580	8.4	72.4	66.4
Dry	546	8.9	74.8	62.5

formed at nearly the same level, while lactating cows showed wide breed differences in weaning per cent, with some breeds being 19 per cent below average weaning percentage and some 18 per cent above the average.

Age of puberty in heifers of various breeds and crosses has been studied in several experiments in the Southeastern United States. Reynolds *et al.*(1963a) estimated the age of puberty of Angus, Brahman, and first crosses to be 433, 816, and 460 days, respectively. *Inter se* bred Brahman-Angus and Africander-Angus heifers averaged 431 and 542 days, respectively. Angus heifers, averaging 536 pounds, were lightest in weight at puberty; first-cross Brahman-Angus averaged 666 pounds, straightbred Brahman averaged 706 pounds, Brahman-Angus averaged 639 pounds, and Africander-Angus averaged 623 pounds. Temple *et al.* (1961) indicated large differences between breeds for age of puberty. The Angus heifers came into heat earlier—about 1 year of age; Herefords were next at 17 months of age, and Brahman at 23 months of age.

Calf Losses

Wiltbank *et al.* (1961) indicated that one of the factors involved in loss of the potential calf crop was death of the calf at or shortly after the time of birth and that failure to conceive or embryonic death occurring before first examination for pregnancy represented the most important factor in reducing calf crop. In a study involving vitamin A injections during pregnancy at the Front Royal station (Meacham *et al.*, 1964a), 6.6 per cent of those receiving vitamin A gave birth to still-born calves, in comparison to 8.8 per cent for those not receiving the vitamin A. Post-natal mortality was 8.1 per cent for those receiving vitamin A and 16.5 per cent for those not receiving the supplement. Further work by these men indicated that supplementation of vitamin A had a favorable effect on calf losses during the first year, but differences between treated and non-treated groups in a subsequent year were not nearly so great.

The survey of experiment station herds in the South revealed that calf losses in most states, as shown in Table 10, were greater for cows which had been dry the previous season, although there was a large variation in differences between wet and dry cows. The calf losses and weaning percentages (does not include calves

sold before weaning) are expressed as percentages of the total number of calves born. Calf losses in the first 36 hours exceeded losses between 36 hours and weaning time by approximately 6 per cent. In general, cows which had been bred when wet weaned a greater proportion of the calves born.

The percentage of calves dead up to 36 hours, expressed as a percentage of the total number born, was greater for cows bred when dry. However, the difference between the wet and dry cows was considerably greater for three-year-old dams than for either the two-year-old dams or the four-year-old and older dams, as shown in Table 11. Even though calf losses from 36

TABLE 11.—AVERAGES FOR THREE FACTORS AFFECTING CALF LOSSES AND PERCENTAGES OF CALVES WEANED, EXPRESSED AS PERCENTAGES OF CALVES BORN, FOR AGE OF DAM AT BREEDING AND LACTATION STATUS*

EFFECTS STUDIED	PERCENTAGE DEAD UP TO 36 HOURS	PERCENTAGE DEAD, 36 HOURS TO WEANING	PERCENTAGE WEANED
Over-all mean	6.9	0.7	[illegible]
Two-year-olds			
Wet	4.3	0.3	[illegible]
Dry	8.4	1.0	[illegible]
Three-year-olds			
Wet	4.2	1.1	[illegible]
Dry	11.6	0.3	[illegible]
Four-year-olds and older			
Wet	3.1	0.7	[illegible]
Dry	5.3	0.8	[illegible]

SUMMARY

Data collected from 1957 to 1960 on reproduction and calf losses in beef herds in the fourteen southern states comprising the Southern Regional Beef Cattle Breeding Project, S-10 were analyzed separately for reproduction of the cows and for calf losses. The factors studied which affected cow reproduction were: (1) percentage of cows removed for reproductive causes, (2) percentage of cows giving birth to calves, both dead and alive, and (3) percentage of cows weaning calves. The factors studied which affected calf losses were: (1) percentage of calves dead up to 36 hours, including those dead at birth, (2) percentage of calves dead 36 hours to weaning, and (3) percentage of calves weaned.

These data indicate that weaning percentages for beef cattle in the South are low and that there is considerable variation among states. Whether cows were wet or dry when bred affected subsequent birth and weaning percentage.

Cows of British breeding that were wet when bred exceeded those bred when dry, for weaning per cent, while cows having Zebu breeding showed the reverse trend.

The percentage of calves lost from birth to weaning, expressed as the percentage of total calves born, was less for cows bred when wet than for cows bred when dry.

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A. C. WARNICK

Reproductive Performance in Florida

Florida has had the lowest per cent calf crop of all states in the U.S.A. for many years, according to the U.S.D.A. figures. In the U.S.D.A. report for 1965, the calf crop for Florida was 75 per cent, which is approximately 11 per cent below the national average. Although this position is not good, it points up the importance of studies to determine the reasons for this low reproduction rate. All data presented in the following tables are based on the number of cows in the herd during the breeding season.

Age and Lactation Factors in Reproduction

In an earlier survey (Warnick *et al.*, 1960) of over 10,000 cows, a comparison was made of age and lactation status in ranch and experiment station herds. The overall pregnancy rate on 13 ranches was 69 per cent (Table 12) compared to 77 per cent in five station herds. It is possible that a higher nutritional plane and a more carefully controlled breeding season in station herds would explain a part of this difference. However, this comparison is not so important as the age and lactation differences. The 61 per cent pregnancy in two-year-old heifers being bred for the first time is very low. This low level would indicate that many heifers had not come into heat as a result of inadequate nutrition and were too small. In one ranch where heifers were small and the ovaries were underdeveloped, only 15 per cent were pregnant after a four-month breeding season.

In both three- and four-year and older cows there was a lowered pregnancy rate in cows lactating during the breeding season

(Table 12). This lowered reproduction in the lactating cow is also shown in Table 13, in which the lactating cows weaned 21 per cent less calves than the nonlactating cows. From other studies it appears that the problem is a failure of ovarian activity and heat rather than conception. Since the energy requirements for lactation are much higher than a nonlactating cow, it is possible that there is inadequate forage to satisfy the requirements for lactation and reproduction. Nutrition in the young lactating cow

TABLE 12.—AGE AND LACTATION EFFECT ON PREGNANCY PERCENTAGE IN FLORIDA COWS (1953-1957)

Group	2 yrs.	3 yrs.		4 yrs. & older		Total	
		lact.	nonlact.	lact.	nonlact.	No.	%
Ranches	61	44	73	61	86	7486	69
Experiment Stations	83	62	79	77	84	2684	77

TABLE 13.—LACTATION EFFECT ON WEANING PERCENTAGE AT RANGE CATTLE STATION, ONA (1944 to 1958)

Group	Weaning percentage
Nonlactating* cows	84
Lactating* cows	63
All cows	73

*Condition during the breeding season.

is especially important, since growth is taking place in addition to lactation. It has been shown that reproduction is inhibited in lactating beef heifers on a lowered nutritional level (Witt *et al.*, 1958).

RANCH DIFFERENCES

There was a large variation in the pregnancy rate among the various ranches as shown by a range from 48 per cent to 89 per cent (Table 14). This would indicate the environment is adequate for good reproduction since some ranches were able to get reproduction above 80 per cent. Although specific reasons for differences in pregnancy rate among the ranches are not known, it was obvious that a better plane of nutrition and improved management were practiced in ranches getting the highest reproduction rate.

TABLE 14.—RANCH DIFFERENCES IN PREGNANCY PERCENTAGE

RANCH NO.*	PREGNANT	RANCH NO.*	PREGNANT
1	48	7	61
2	49	8	65
3	54	9	73
4	55	10	80
5	58	11	83
6	60	12	84
		13	89

*No. cows per ranch varied from 107 to 1,233.

YEAR DIFFERENCES

The average calf crop in 14 to 17 commercial ranches from 1959 to 1963 was 71 per cent (Table 15) which is similar to the 69 per cent pregnancy rate in Table 12. There was an increase from 67 per cent in 1959 to 75 per cent in 1963, indicating some improvement is being made. Similar improvement is shown in Table 16 where the pregnancy rate went from 67 per cent in 1953 to 80 per cent in 1957. In another study of 11 ranches (Table 17) the

TABLE 15.—CALF CROP PERCENTAGES ON RANCHES IN VARIOUS YEARS IN SOUTH FLORIDA

YEAR	NO. RANCHES	CALF CROP
1959	15	67
1960	16	71
1961	15	67
1962	14	73
1963	17	75
	—	—
Average	16	71

Source: Alston (1963).

TABLE 16.—YEAR DIFFERENCES IN PREGNANCY RATE IN FLORIDA

YEAR	NO. COWS	PREGNANCY
1953	739	67
1954	1,863	65
1955	1,465	68
1956	4,746	73
1957	1,337	80
	—	—
Total cows and average	10,170	71

TABLE 17.—COMPARISON OF CALF CROP ON ELEVEN FLORIDA RANCHES

YEAR	AVG. NO. COWS	% CALF CROP
1961	1,202	65
1962	1,314	72
1963	1,393	76

Source: Alston (1964).

calf crop was 65 per cent in 1961 compared to 76 per cent in 1963. It is suspected that these increases were a result of ranchers becoming aware of their low reproduction rate and taking steps to improve their management programs. However, it is realized that year to year variation in rainfall, forage production, etc., can influence calving percentage so it is difficult to evaluate overall, long-term improvement in reproduction.

The pregnancy rate from 1953 to 1964 shown in Table 18 for

TABLE 18.—PREGNANCY RATE IN CROSSBRED COWS AT BEEF RESEARCH UNIT, GAINESVILLE, FLORIDA

YEAR	PREGNANCY	YEAR	PREGNANCY
1953	44	1959	92
1954	55	1960	93
1955	82	1961	93
1956	86	1962	96
1957	88	1963	95
1958	88	1964	92*

*1953 to 1963—3 month breeding season; 1964—2½ month breeding season.

crossbred cows at the Beef Research Unit in Florida indicates that improvement can be made in reproduction. These percentages are based on all females two years and older which were bred during a three month breeding season (except in 1964 when a 2½ month breeding season was used) beginning on March 1. The culling procedure for reproduction was to cull all the original cows after the second failure to become pregnant either in consecutive or alternate years. All replacement heifers not pregnant after the first breeding season were culled. In later years all nonpregnant cows were culled. A marked increase in reproduction occurred in 1955, probably as a result of culling many of the original cows with low fertility and the addition of the first

group of replacement heifers, three-fourths of which were sired by British bulls. The nutritional level was improved, which could account for a part of the increased reproductivity. The most important fact is that the reproductive level increased from a low rate to a very satisfactory level in a relatively short period. Ranchers should be able to make similar progress by culling noncalving cows, by improving the nutritional plane and improving the overall management system.

SUMMARY

The calving rate in Florida commercial cows appears to be approximately 70 per cent, which is 16 per cent below the national average. However, surveys from two sources indicate ranchers are increasing their calf crops in recent years. Since some ranchers are getting good reproduction, it would indicate that the climate in Florida is not an important limiting factor. The variation in pregnancy rate on 13 ranches varied from 48 to 89 per cent, indicating that by good management a satisfactory calving rate can be attained.

The low reproduction rate in heifers being bred for the first time indicates they are not of adequate size or sexually mature. This is probably due to inadequate nutrition, especially during their first two winters. Since cows lactating during the breeding season had lower pregnancy rates than nonlactating cows, it would appear that nutrition is inadequate for milk production and reproduction, especially in young cows.

A marked improvement in calf crop has been demonstrated at the Beef Research Unit Station herd at Gainesville, Florida, where strict culling for failure of pregnancy is practiced, an adequate year-around nutritional level is maintained and the breeding season is properly controlled. Ranchers should be able to increase their reproductive rate by recognizing the problem, culling the nonbreeders, having adequate nutrition, and improving their overall management, including control of the breeding season.

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L. S. POPE

Winter Feeding and Reproduction in Cows

One of the most striking trends affecting the beef industry is the increasing proportion of total beef cattle represented by breeding age females (40 per cent of total beef cattle numbers). The trend has been very evident since World War II and is even more striking when we consider that total beef cattle numbers have almost doubled during this period. That we have more beef cows is a direct reflection of the more intensive systems of production prevalent today, with a short interval from birth to market.

The second important item is where the nation's beef cows are located. No other area has advanced as rapidly in beef numbers as the Southeast. The 11 Southeastern states, which had only 14 per cent of the nation's beef cows in 1945, now have nearly 25 per cent of the total.

Florida, with approximately 800,000 beef cows, ranks 3rd behind Mississippi and Louisiana among the 11 Southern states. With long grazing seasons, improved parasite and disease control, and Bermuda or other improved pastures, the Southeast has made tremendous strides in the production of feeder calves. Moreover, the quality of cattle in this area has improved rapidly. This has occurred while other significant changes have been taking place in the beef industry, i.e., a shift in cattle feeding to the Plains states and West Coast, and a surprising increase in beef cow numbers in the Corn Belt.

This serves to emphasize that the beef business is dynamic, and that many more changes will come about as we seek greater production at reduced cost. No longer can one geographic area or

state lay claim to superiority or an "insulated position" in the beef business. This is especially true with cow-calf and feedlot operations. As we expand beef production, it is obvious that we need to improve production from the brood cow—the weakest link in the endless chain representing the beef industry.

Nature of the Beef Female

Let us consider first the special characteristics that set a beef cow apart from females of other species. Beef females are slow to reach sexual maturity and begin reproduction at a later point in life than the sow or ewe. The growth period is longer than is common in many other species, and nearly five years are required before an average beef cow reaches her peak in body weight and size.

A long gestation period is required to produce a live calf, with less than one offspring yearly (considering an 85 per cent calf crop). The calf at birth represents less than 7 per cent of the body weight of an average beef cow. Milk production is notoriously low in beef females, and the lactation curve appears to be more abrupt than is the case with dairy cows. At the Fort Reno (Okla.) Station one summer, the 6 best four-year-old cows in an experimental herd averaged only 14.3 pounds of milk daily from March to September.

The useful life span of the average range cow in most herds is probably less than 7 calf crops. In a recent survey involving 776 cows in a large purebred herd in Oklahoma, the average beef cow lasted only 9.2 years and left only 4.6 offspring in the herd. Such attrition in cow numbers means that nearly 1/3 of all heifer calves dropped must be retained as replacements. From 2.5 to 3.5 years may elapse from the time a heifer is born until she weans her first calf.

Because of the way she is fed and managed, a number of factors must be considered when we look at the nutritional spectrum of the beef female. During the summer, cows on good pasture can store up large body reserves of energy, vitamin A, calcium and phosphorus. These can be used to meet a part of her needs during the winter while on sparse feed. This is strictly an advantage and helps cut wintering costs. On the other hand, if fed so liberally so that she fattens excessively, milk yields of the cow may be reduced and life span shortened. Fertility may be impaired and a

higher disease loss may occur as the result of superabundant feed.

Cow-calf operators must take a close look at the financial return from the 3.5 tons of dry matter required each year to maintain a brood cow. Generally, the yield of saleable calf is far less than 400 pounds per cow, considering average weaning weights and 85 per cent calf crops.

In many areas of the South, supplemental winter feed is necessary. Often considerable roughage must be fed at rather high cost to bring a cow through the winter. Because winter feed is the most expensive item in many operations, researchers have tried to reduce this "overhead cost" of maintenance by a better knowledge of the exact needs of the beef cow.

Level of Wintering Experiments

In the following discussion we will draw on results from experiments at several stations, notably the good research at Nebraska and Florida, as well as that obtained from U.S.D.A. studies over the past few years. One of the most extensive has been Oklahoma winter feeding studies, largely at the Ft. Reno Station.

Cow-herd experiments at this station have been in progress for over 20 years, chiefly at the Lake Blackwell range unit in north central Oklahoma and at Ft. Reno in the central part of the state. In both areas, beef females, from weaner heifer calves to mature cows, have grazed native range grass year-long, with protein and mineral supplements during the winter period (November to mid-April) as needed to produce the desired gain or loss.

In one project alone, we now have data on more than 680 beef females and 1,930 calves from cows fed different amounts of winter feed. In one study, the cows have been on continuous tests for over 14 years to determine the accumulative effects of different winter feeding regimes. In other studies, the effects of plane of nutrition have been observed with fall-calving cows, and in another study 12 sets of identical twins were used to obtain basic data on growth, fertility and milk production.

From an overall standpoint, it is most meaningful to divide the nutrition of a beef female into three categories: (1) *Early growth and development to 18 months of age,* which includes the first breeding performance and recovery from winter loss on summer grass, (2) *nutrition of bred yearlings and young* cows,

including the effects of winter feed on time of calving, per cent calf crop weaned, rebreeding, average weaning weight and cost of production, and (3) *the mature beef cow,* as different wintering regimes may affect total calf output, life-span in the herd, and the cause of removal from the herd or death loss.

Obviously, there is much we know and do not know about the best and most economical way to rear a replacement heifer, get her into production at an early age, and maintain her at the highest fertility level over the longest life span possible. In other words, the problem is to get the greatest possible "turn off of calf" at weaning—in line with most economical production.

Different planes of winter nutrition were achieved in Oklahoma studies by varying the supplemental winter feed at frequent intervals to establish a prescribed gain or loss of body weight. "Low Level" heifers have been retarded the first winter as weaner calves so that no gain was possible. The following year, as bred females, they were fed to lose 20 per cent or more of fall weight by spring (after calving). In the "Moderate" regime, heifer calves gained 0.5 pound per day, or 75-100 pounds during the first winter as calves. As bred females, they lost less than 10 per cent of fall body weight.

Heifers on a "High Level" gained over 1.0 pound per head daily as weaner calves, and lost only 5 to 10 per cent of fall weight during the winter. In order to obtain an extreme plane of nutrition, a "Very High Level" was practiced where heifers were full-fed on fattening rations for maximum gains each winter. In these studies, all heifers were bred to calve first as two-year-olds (February and March calving). Ample pasture was available throughout the year, but the protein content of dry, weathered grass during the winter dropped to only 3 to 4 per cent.

Nutrition During Growth and Early Production

The period from weaning to 18 months of age is critical in the life of the young heifer. Results of 5 trials in which different levels of winter feeding have been practiced to 3.5 years of age are summarized in Table 19. If fed poorly as a weaner calf, the yearling replacement heifer fails to reach sexual maturity and initiate a regular estrual cycle, as compared to well-fed females, early enough to permit two-year-old calving (see Table 20). On the average, they conceive about a month later, even on lush sum-

TABLE 19.—EFFECT OF WINTER FEED LEVELS* ON PERFORMANCE OF HEIFERS TO 3.5 YEARS OF AGE IN OKLAHOMA TRIALS (AVG. OF 5 TRIALS)

	LOW	MODERATE	HIGH
Avg. initial weight at 8 mos., lb.	486	486	486
Avg. winter weight loss, lb.			
1st winter—weaner calves	+8	+90	+155
2nd winter—bred yearlings	−166	−100	−38
3rd winter—bred two-year-olds	−146	−60	+20
Avg. body weight, 3.5 years, lb.	1000	1061	1099
Avg. supplemental winter feed, lb.			
C.S. meal	.40	1.90	2.35
Ground milo	.10	.75	4.50
Avg. calving date,			
1st calf	*3/14*	*3/7*	*2/25*
2nd. calf	3/25	3/13	2/27
Avg. birth weight (sex corrected),			
1st calf	64.3	70.7	73.7
2nd calf	71.0	77.2	78.6
Avg. calf crop weaned, %			
1st calf	73.2	79.5	80.7
2nd calf	79.8	85.6	83.0
Avg. weaning weight (sex corrected),			
1st calf	347	398	429
2nd calf	376	439	474
Avg. calf "turn-off/heifer" bred, 3.5 years of age, lb.	554	692	740

*Winter gain or loss was achieved by varying the supplemental feed on dry grass at 2-week intervals. In general, Low females receive less than 1.0 lb. of cottonseed meal and milo supplement per head daily, Moderates 2.5 lb., and High 2.5 lb. C.S. meal and 4-6 lb. ground milo. A mixture of 2 parts salt and 1 part bone meal was available, year-long.

TABLE 20.—EFFECT OF WINTER FEED LEVEL ON AGE OF HEIFERS AT PUBERTY

AGE IN MONTHS	% SHOWING 1ST HEAT		
	LOW	MODERATE	HIGH
9	4	4	—
10	17	13	10
11	30	33	47
12	47	57	70
13*	60	64	90
14	63	73	93
15	70	90	100
16	87	97	100
17	93	100	100

*End of wintering period.

mer pasture, than well-wintered heifers, and many fail to breed at all during the first summer.

In terms of body size, however, much of their skeletal pattern (nearly 70 per cent of mature height and length) is already established before the start of the first winter at 8 months of age. A low plane of nutrition during the first winter (8 to 13 months of age) seems to have only slight effect on height, length or width at maturity. Skeletal size and frame are recovered to a remarkable extent during the summer if pastures are good.

If heifers are subjected to a low plane of nutrition as calves so as to lose weight from fall to spring, but are well-fed thereafter, Oklahoma studies show that the only significant carry-over effect seems to be delayed conception. However, if the summer pasture is insufficient following a poor wintering program, they may fail to come into heat at all during the mating season. The adverse effects of low winter feed levels on body weight or skeletal size seem to be recovered to an amazing degree if good summer pasture is available. This pattern for recovery has also been observed in U.S.D.A. studies by Winchester, using identical twins, where one member was retarded for a six-month period and both were then full-fed to slaughter condition.

On the other hand, too liberal feeding during the growth period may be just as injurious to the beef female. A "Very High" plane of nutrition speeds up growth and development of beef heifers and thus increases their "physiological age" at first calving. However, this may not be desirable in all respects. Excessive calving difficulty due to a large fetus and obstruction from internal fat may occur. Fatty deposits in the udder may result in poor milk yields. Early maturity and excessive feeding may actually shorten the life span of a beef cow. If the heifer does not conceive and calve before 27 months of age, fertility is greatly affected by an excessively high plane of nutrition.

With this in mind, the practice of "gain testing" a weaner heifer calf to determine growth potential is a questionable one. Even creep-feeding a suckling heifer calf may be undesirable, if she is to be saved back as a replacement heifer.

Nutrition During the First and Second Calf Crops

The results of poor winter feeding as a bred yearling and as a two-year-old show up in (1) delayed calving which, in turn, may delay subsequent conception as a result of the first winter's treat-

ment as a weaner calf, (2) lighter birth weights of 6 to 8 pounds, with a less vigorous calf at birth, (although calving difficulty may not be increased because of the small fetus), and (3) reduced milk flow after calving and throughout the summer grazing period.

As a consequence, weaning weights of calves from heifers wintered for two or three consecutive years at the Low Level have averaged 90 pounds lighter than those from High Level heifers. However, as the females advance in age, differences become smaller (see Figure 3). The per cent calf crop weaned has been reduced about 5 per cent by poor winter feeding. A combination of fewer calves and lighter weaning weights has reduced the

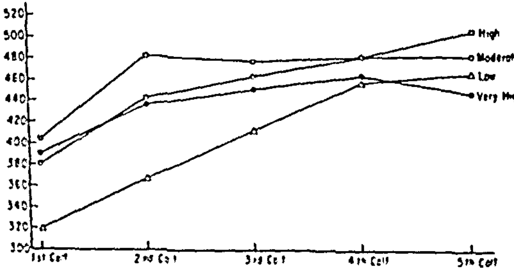

FIGURE 3. Average weaning weights of successive calf crops produced by cows wintered at different levels.

weighing the calf in and out, twice daily, at monthly intervals during the summer. Low Level heifers produced only 60 per cent as much milk as those on the High Level (Table 21). This occurred even though the heifers were on excellent summer grass (see Figure 4).

Dairymen have long recognized the importance of building up the female and the secretory tissues in her udder, prior to each

TABLE 21.—EFFECT OF FOUR DIFFERENT WINTER FEED LEVELS ON GROWTH AND REPRODUCTIVE PERFORMANCE OF BEEF COWS TO 6.5 YEARS OF AGE.

	Low	Moderate	High	Very High
Initial body wt. at 8 mos., lb	473	472	475	488
Avg. winter gain or loss, lb.				
1st winter—calves	−11	97	145	280
2nd winter—bred yearlings	−212	−150	−70	156
5th winter—mature cows	−285	−256	−165	197
Avg. fall body wt. at 6½ yr., lb.	1191	1240	1289	1480
% cows remaining at 6½ yr.	87	87	80	80
Avg. calving date, March	17	19	2	4
Avg. birth wt., lb.	73	76	79	73
% calf crop weaned	85	85	87	[illegible]
Avg. weaning wt., sex corrected, lb.	404	449	471	427
Avg. daily milk prod., lb.	10.0	11.5	12.2	10.1
Total supplemental feed cost/cow, $	15.30	73.80	[illegible]	671.72

TABLE 22.—INFLUENCE OF LEVEL OF WINTER FEEDING ON LIFETIME PERFORMANCE OF BEEF COWS, 1948-1962.

	AMOUNT OF DAILY WINTER SUPPLEMENT TO DRY WEATHERED GRASS/HEAD		
	1 LB. CSM*	2½ LB. CSM	2½ LB. CSM 3 LB. OATS
No. heifer calves started on test, 1948	30	30	30
No. cows remaining, 1958	27	21	18
No. cows remaining, Oct. 12, 1962	16	11	5
Avg. cow-years on test	12.7	11.6	10.7
No. cows removed for:			
Failure to wean a calf two successive years	6	9	9
Cancer eye	1	4	5
Spoiled udder	2	1	4
Disease	0	1	2
Accidental death	1	0	0
Died at calving	0	0	1
Crippled	1	2	1
Foreign objects	1	0	2
Unknown	2	2	1
TOTAL	14	19	25
Avg. winter gain, lb.			
As calves	23	60	68
As bred yearlings	−90	−52	−26
Avg. for 1950-60 period	−162	−159	−115
Avg. mature body wt., lb.	1142	1147	1194
Reproductive performance:			
Avg. birth wt., lb.†	77.6	77.6	78.8
Avg. weaning wt., lb.†	479	482	483
Per cent calf crop weaned	90.3	83.9	83.8
Cow-cost per cwt. calf weaned	7.59	10.69	14.28

*41 per cent cottonseed meal pellets
†Corrected for sex to steer equivalent

is evidence that cows on the lower feed levels are better "rustlers" and more active in their grazing habits. This may have had a bearing on their mothering ability and shows up in the fact that only half as many calves were lost from birth to weaning in this group.

NUTRITION AND LIFE SPAN

Due to the high cost and long interval required to develop a replacement heifer and get her into production, a maximum life span of the beef female is of great economic importance. A longer life-span for top producing cows gives the breeder more opportunity to select superior offspring for herd replacements. To date, few studies have been continued over a sufficient time interval to indicate whether or not winter feed levels affect life-span.

In a group of females started on test as weaner calves in 1948 and carried past 14 years of age, some estimate of this effect can be made (see Table 22). Thirty females in each of three groups were wintered on dry grass plus either 1.0 pound cottonseed meal, 2.5 pounds of cottonseed meal, or 2.5 pounds cottonseed meal plus 3.0 pounds grain daily for each succeeding winter. The results in terms of cow survival have been remarkable. At 14 years of age, with no culling other than for failure to raise a calf two successive years or for disease and unsoundness, there were 16, 11 and 5 cows out of 30 started on test surviving from the 1.0 pound, 2.5 pounds, or 5.5 pounds feed levels, respectively. Cows on the 1.0 pound level survived an average of 2 more years on test.

The reasons for this longer life-span at the 1.0 pound level are not clear. It may be related to an elongated growth phase, which may add to the total life-span of the individual. Maintenance of smaller body size may be an advantage, as has been noted in the human. The "stress" imposed by the summer build-up and winter loss of body weight may be nature's way of stimulating certain body processes for the good of the individual. If not carried to excess, all of these may act to prolong the health and useful life of a beef cow.

Obviously, these effects can be reversed if severe undernourishment is practiced, or if the shortage of a specific mineral or vitamin A becomes acute. However, the data suggest that once a beef female meets her needs for optimum growth and reproduction, superabundant feed may become a liability. This concept is

especially important to purebred cattlemen who "never let them go hungry" under the impression that such a practice increases the life-span, breeding efficiency, and productivity of a female.

SUMMARY

Low planes of winter nutrition for the growing beef heifer have only a slight effect on the body weight and skeletal size at maturity, providing good recovery is possible on summer pasture. Estrus may be seriously delayed, or cease entirely, and this reduces or "strings out" the subsequent calf crop. With older heifers, low levels of wintering can seriously affect milk flow on summer grass. Together, the combined effects of delayed calving, lighter birth weight, and reduced milk yield may seriously depress weaning weights and the pounds of calf "turned off" per female maintained in the herd.

Mature cows are able to withstand the effects of poor winter feed conditions to a remarkable degree, providing good summer pasture is available so that body weight can be maintained from fall to fall. Weaning weights of spring-dropped calves from mature cows may be only slightly affected. Since the spring-calving female breeds back on good summer grass, the calf crop percentage may not suffer. However, if feeding conditions are poor during breeding, the adverse effect on calf crop will be serious. Under fall-calving conditions, more feed will be required to meet the cow's protein and energy requirements, especially if we develop higher production in our females.

Once the optimum plane of nutrition is reached for any age or condition, superabundant feed may prove both costly and detrimental. Experiments indicate that the *range between too poor and too high feed levels may be quite narrow and critical.* Whether or not beef heifers can be fed liberally early in life, then reverted to a low level at maturity in order to combine the best results of both systems has not been determined. For spring-calving heifers, the Moderate program described above seems to combine optimum growth and most profitable performance.

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J. N. WILTBANK

Level of Energy and Protein in Cows

Reproductive performance of a beef cow herd can be markedly improved by providing adequate nutrition. Nutrition improves reproductive performance by (1) causing heifers to have their first heat at an earlier age, (2) increasing the number of cows showing heat the first 21 days of the breeding season, and (3) increasing the number of cows conceiving at first service.

Results from 3 experiments show that the age at first heat is dependent on energy level. In the first experiment heifers were fed 3 levels of energy and 3 levels of protein. Level of TDN fed was approximately 11 pounds in the high group, 6 pounds in the medium group and 3 pounds in the low group. Digestible protein level was over 1 pound in the high group, approximately 0.8 pound in the medium group and 0.3 pound in the low group. All heifers receiving the high or medium level of TDN and either high or medium levels of protein came into heat (Table 23). Fourteen heifers out of 32 showed heat on the low level of TDN. However, most of these heifers showed heat only one or two times and then stopped showing heat. In fact, only 6 heifers continued to cycle. Fourteen heifers out of 24 on low levels of protein and either high or medium levels of energy showed heat. Four of these stopped cycling. Considerable variation in the intake of feed was noted in these heifers on low protein level. Heifers eating the larger amounts of feed showed heat. The number of days from start of experiment to first heat did not appear to be related to feed level. We can conclude that a limited number of heifers on low energy levels will show heat. Low protein also limits the number of heifers showing heat prob-

ably by decreasing feed consumption and thus intake of energy.

Winter feed level of heifer calves influences the age at first heat. For two years heifer calves were wintered on grass and 1 pound of protein supplement daily. They gained approximately 0.5 pound per day during the winter. The following two years heifers were fed alfalfa hay and grain. They gained approximately 1 pound per head per day. Wintering heifers on the higher level of feed decreased the average time of first heat and increased the number of heifers in heat at 14 and 15 months of age in

TABLE 23.—TIME OF FIRST HEAT ON DIFFERENT LEVELS OF ENERGY AND PROTEIN

Level of Feed: TDN	Level of Feed: Dig. Protein	No. of heifers	ADG*	Heifers showing heat (No.)	Days from start of experiment to heat	Heifers [illegible] (No.)
High (11 lb.)	High (1.5 lb.)	12	1.6	12	[illegible]	0
High (12 lb.)	Medium (0.9 lb.)	12	1.5	12	[illegible]	0
High (6 lb.)	Low (0.2 lb.)	12	.27	6	112	2
Medium (6 lb.)	High (1.3 lb.)	12	.77	12	[illegible]	0
Medium (6 lb.)	Medium (0.8 lb.)	12	.84	12	[illegible]	0
Medium (6 lb.)	Low (0.3 lb.)	12	[illegible]	8	[illegible]	2
Low (3 lb.)	High (1.1 lb.)	9	[illegible]	7	[illegible]	3
Low (3 lb.)	Medium (0.7 lb.)	11	.12	7	[illegible]	4
Low (4 lb.)	Low (0.4 lb.)	12	[illegible]	4	[illegible]	1

*Average daily gain in pounds.

TABLE 24.—EFFECT OF WINTER FEED ON AGE AT FIRST HEAT

Breed of heifer	Heifers wintered to gain 0.5 lb. per head per day: No. of heifers	Age at puberty	Heifers in heat by: 14 mo.	15 mo.	Heifers wintered to gain 1.0 lb. per head per day: No. of heifers	Age at puberty	Heifers in heat by: 14 mo.	15 mo.
		mo.	%	%		mo.	%	%
Angus	30	13.2	57	77	25	11.2	80	92
Hereford	27	15.2	22	41	26	13.8	62	77
Shorthorn	32	13.8	56	91	26	10.6	85	92
Crossbred heifers								
Angus-Hereford	33	13.2	73	91	28	12.0	82	96
Angus-Shorthorn	35	12.2	77	94	31	10.1	97	100
Hereford-Shorthorn	33	12.7	82	94	36	10.0	97	100

feed while heifers on the low level of feed gained from 0.6 to 0.8 pound per day.

There was little or no difference between breed groups in the age at first heat on the high level of feed, while marked differences in age at first heat were noted in heifers on low levels of feed. All heifers except one (a Hereford-Angus crossbred) on the high level of feed had been in heat by 14 months of age (Table 25). Only 12 per cent of the Hereford heifers on the low level of feed had been in heat by 14 months of age while 33 per cent of the Angus heifers and 70 per cent of the crossbred heifers had shown heat at this time. By 15 months of age there were still

TABLE 25.—AGE AT FIRST HEAT ON TWO LEVELS OF FEED

Level of feed	Breed of heifer	No. of heifers	Wt. at 5 mo. in lbs.	A.D G.*	Per cent in heat by: 12 mo.	13 mo.	14 mo.	15 mo.	16 mo.
High†	Angus	12	301	1.7	33	58	100	100	100
	Hereford	8	288	1.5	12	50	100	100	100
	Hereford-Angus	17	309	1.8	18	76	94	94	100
Low‡	Angus	12	317	0.8	0	0	33	75	75
	Hereford	8	297	0.6	0	0	12	12	12
	Hereford-Angus	17	330	0.8	0	12	70	88	88

*Average daily gain in pounds.
†Full-fed.
‡Grass hay fed *ad libitum* plus 1 pound of 40 per cent protein supplement.

only 12 per cent of the Hereford heifers in heat but 75 per cent of the Angus and 88 per cent of the crossbred had shown heat.

The results of these three experiments show that the age of first heat differs markedly in heifers wintered at different levels of feed their first winter or receiving different levels of energy from weaning to first heat. Low levels of protein may also delay first heat but this appears to be the result of decreasing the appetite and thus decreasing the amount of feed the heifers eat.

More cows became pregnant when fed high levels of energy following calving. This increase resulted because more cows were bred early in the breeding season and more cows settled at first service. The results from 3 experiments will show the importance of energy level on reproductive performance. In the first experiment, mature Hereford cows were put on either a moderate or a low level of feed (9.0 pounds of TDN and 4.5 pounds of TDN) approximately 140 days prior to calving. The cows on the moderate level were divided at calving into a group receiving 16 pounds of TDN (moderate-moderate group) and a group receiving 8 pounds of TDN (moderate-low group). The low group after calving was divided also into a low-moderate group (16 pounds TDN after calving) and a low-low group (8 pounds TDN following calving). Weight gains varied according to feed level. Cows on the moderate level of feed prior to calving gained weight and were in good condition at calving time. Cows on the low level of feed prior to calving lost more than 100 pounds and were thin at calving time (Figure 5). After calving the weight of cows in the moderate-moderate group changed very little. Cows in the moderate-low group lost weight at the rate of more than 1 pound per day. Little change in weight was noted for cows in the low-moderate group from calving until 60 days after calving; then they started gaining weight rapidly. Cows in the low-low group lost weight throughout the period after calving.

Reproductive performance was related to weight gains or losses. Pregnancy rate of cows losing weight was low. Only 77 per cent of the moderate-low cows and 20 per cent of the low-low cows became pregnant in a 90-day breeding season. In contrast 95 per cent of the cows in the moderate-moderate and low-moderate group became pregnant (Table 26). The number of cows conceiving early in the breeding season was related to feeding level both before and after calving. Forty-three per cent of the cows in the moderate-moderate group, 32 per cent of the

cows in the moderate-low group, 30 per cent of the cows in the low-moderate group, and 10 per cent of the cows in the low-low group became pregnant in the first 20 days of the breeding season. This same trend was apparent after 40 days of the breeding

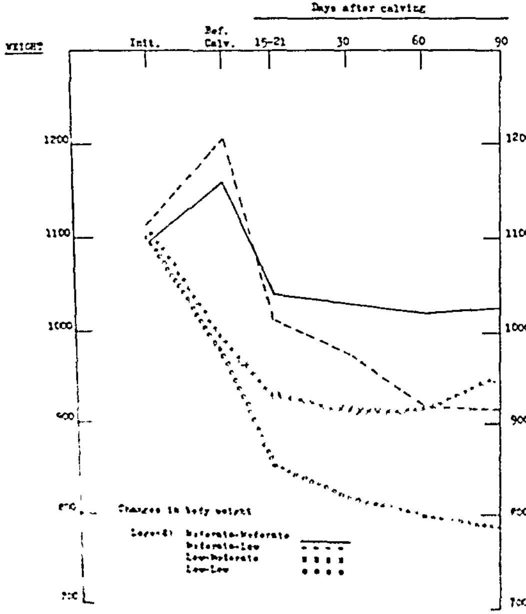

FIGURE 5.

season except more cows in the low-moderate group were pregnant than cows in the moderate-low group.

Poor reproductive performance was a result of failure to show heat during the breeding season and a low conception rate at first service. Seventy per cent of the cows in the low-low group and

TABLE 26.—ENERGY LEVEL AND REPRODUCTIVE PERFORMANCE OF MATURE HEREFORD COWS

LEVEL OF TDN			COWS PREGNANT			COWS NOT IN HEAT BY:			
[illegible]EFORE [illegible]ALVING	AFTER CALVING	NO. OF COWS	1ST 20 DAYS OF BREEDING SEASON	1ST 40 DAYS OF BREEDING SEASON	90-DAY BREEDING SEASON	1ST 20 DAYS OF BREEDING SEASON	1ST 40 DAYS OF BREEDING SEASON	90-DAY BREEDING SEASON	CONCEIVED BY FIRST SERVICE
			%	%	%	%	%	%	%
[illegible]oderate [illegible].0 lb.)	Moderate (16.0 lb.)	21	43	81	95	38	10	0	67
[illegible]oderate [illegible].0 lb.)	Low (8.0 lb.)	22	32	45	77	32	14	14	42
[illegible]ow [illegible].5 lb.)	Moderate (16.0 lb.)	20	30	60	95	60	15	5	65
[illegible]ow [illegible].5 lb.)	Low (8.0 lb.)	20	10	15	20	75	70	70	33

14 per cent of the cows in the moderate-low group failed to show heat during the breeding season. Conception rate at first service was 42 per cent for the moderate-low group and 33 per cent for the low-low group in contrast to 67 and 65 per cent for the moderate-moderate and low-moderate group. Thus, feed level after calving has a marked effect on the number of cows becoming pregnant in the breeding season.

The low feed level prior to calving delayed the occurrence of heat. Sixty per cent of the cows in the low-moderate group were

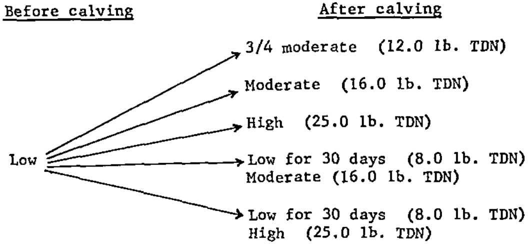

FIGURE 6. Outline of Experiment.

not bred the first 20 days of the breeding season. This is in contrast to 38 per cent in the moderate-moderate group. By the 40th day of the breeding season, the difference between the two groups was only 5 per cent. These data show that cows should be either gaining in weight at breeding time or should be in good condition with no weight loss occurring near breeding time. Poor reproductive performance in this experiment was the result of a failure to show heat and a low conception rate.

We next compared the reproductive performance of cows gaining weight at different rates following calving. Mature Hereford cows were put on 4.5 pounds of TDN approximately 140 days prior to calving. At calving time the cows were divided into 5 groups receiving the following amounts of TDN: 12.0 pounds TDN (3/4 moderate), 16.0 pounds TDN (moderate), 25.0 pounds TDN (high), 8.0 pounds TDN for 30 days then 16.0 pounds TDN (low-moderate), 8.0 pounds TDN for 30 days then 25.0 pounds TDN (low-high). (See Figure 6 for outline).

All cows were thin at calving time. The weight gains after

calving varied according to the feed level. The 3/4 moderate group showed little change in weight from 28 days to 84 days after calving. The moderate group showed a slight increase in weight while a marked increase in weight was noted in the high group (Figure 7). Cows on the low level of feed for 30 days lost weight rapidly during the 30-day period. Following this time a moderate increase in weight was noted in the low-moderate group and marked increase in weight occurred in the low-high group.

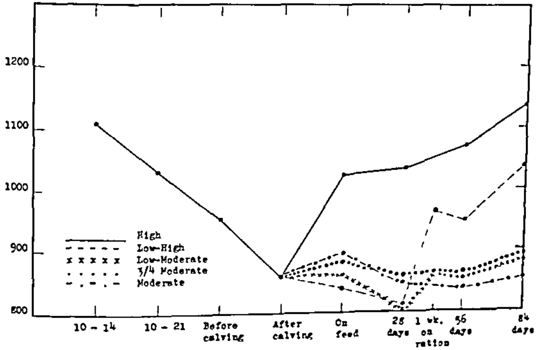

FIGURE 7. Weight gains of cows on experiment to show effect of different energy levels fed to thin cows following calving.

The poor reproductive performance in all groups was a result of a delay in occurrence of heat and a low conception rate at first service. Sixty-nine per cent of the high cows and 87 per cent of the low-high cows had not shown heat by the first 20 days of the breeding season. This is in contrast to 21 per cent in the moderate group, 86 per cent in the 3/4 moderate group, and 62 per cent in the low-moderate group. Thus, the onset of heat after calving was delayed in cows on a high level of feed or on the low level or 3/4 moderate level. The conception rate at first service

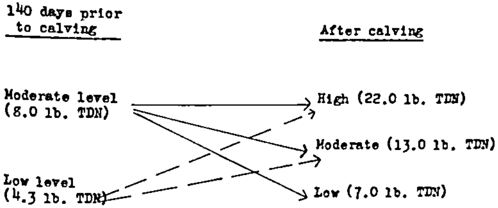

FIGURE 8. Outline of Experiment.

was 83 per cent for the high cows and 87 per cent for the low-high cows while the conception rate at first service in the other groups varied from 31 to 54 per cent.

These data show that cows gaining rapidly in weight following calving have better reproductive performance than cows making little or moderate gains. However, the onset of heat appears to be delayed in cows on these high levels of feed.

The next experiment involved 203 two-year-old Angus and Hereford heifers. They were bred as yearlings and started on experiment 140 days before expected calving. They were in dry

Heifers were checked for heat with sterilized bulls wearing marking harnesses. All cows were bred artificially. The breeding started 60 days after calving and ended 120 days after calving. *Heifers averaged 780 pounds at the start of the experiment* (Figure 9). Heifers on the moderate level of feed had gained 133 pounds when weighed a week before calving. By 24 hours after calving they averaged 790 pounds. These heifers were in good flesh throughout the 140-day period before calving.

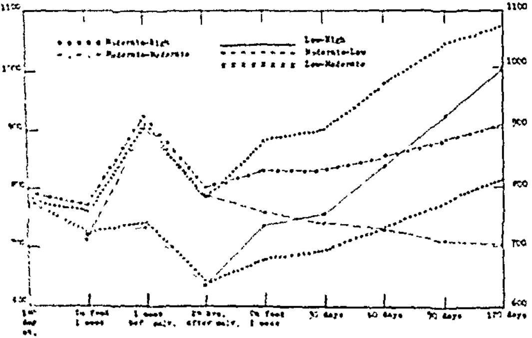

FIGURE 9. Weight gains by nutrition level.

Table 28.—Reproductive Performance of Two-year-old Cows on Different Levels of Energy

Level of TDN		No. of cows	Cows pregnant			Cows not in heat by:		Conceived by first service
Before calving	After calving		1st 20 days of breeding season	1st 40 days of breeding season	60-day breeding season	1st 20 days of breeding season	1st 40 days of breeding season	
			%	%	%	%	%	%
Moderate (8.0 lb.)	High (23.0 lb.)	42	55	78	81	19	7	62
Moderate (8.0 lb.)	Moderate (13.0 lb.)	37	54	65	70	24	5	65
Moderate (8.0 lb.)	Low (7.0 lb.)	42	33	60	64	36	19	53
Low (4.0 lb.)	High (23.0 lb.)	41	51	71	90	27	5	73
Low (4.0 lb.)	Moderate (13.0 lb.)	41	31	49	73	39	17	53

the moderate-moderate, moderate-low, and low-moderate groups became pregnant (Table 28).

The number of cows becoming pregnant in the first 20 days of the breeding season ranged from 51 to 55 per cent for the moderate-high, moderate-moderate, and low-high groups while only 33 per cent of the moderate-low cows and 34 per cent of the low-moderate cows became pregnant in this period. A few more cows were pregnant in the two high groups than in the moderate-moderate group by the 40th day of the breeding season.

TABLE 29.—REPRODUCTIVE PERFORMANCE OF FIRST CALF HEIFERS ON VARIOUS LEVELS OF ENERGY AND PROTEIN

LEVEL OF FEED			DAILY INTAKE OF		HEIFERS SHOWING HEAT AFTER CALVING BY:			
ENERGY	PROTEIN	NO. OF HEIFERS	TDN	DIG. PROTEIN	60 DAYS	90 DAYS	120 DAYS	NO. OF HEIFERS BECOMING PREGNANT
			lb.	lb.	no.	no.	no.	
High	High	10	15.6	2.06	8	9	9	10
High	Medium	10	14.8	1.18	5	8	9	9
High	Low	10	11.4	0.40	3	6	9	10
Medium	High	11	9.4	1.92	7	8	10	11
Medium	Medium	11	10.4	1.38	5	10	10	10
Medium	Low	12	9.1	.50	5	6	7	10
Low	High	8	5.6	1.86	0	0	0	0
Low	Medium	10	5.8	1.20	0	0	0	1
Low	Low	12	5.6	.46	1	1	2	4

Again the differences in reproductive performance can be explained on the basis of occurrrence of heat and differences in conception rate at first service. The number of cows not in heat or bred the first 20 days of the breeding season varied from 39 per cent in the low-moderate group to 19 per cent in the moderate-high group. Conception rate at first service varied from 73 per cent in the low-high group to 53 per cent in the moderate-low group and the low-moderate group. These results show that the reproductive performance of cows is improved when they are gaining weight following calving.

Some work has been done on the effect of levels of protein on reproductive performance of cows suckling calves. The results indicate that a low level of protein may delay the onset of heat following calving. Three levels of energy and three levels of protein were fed in this experiment. Table 29 shows the amount of

TDN and digestible protein each heifer received. Four heifers in the high energy-low protein and 6 in the medium energy-low protein had not shown heat by 90 days after calving. This is in contrast to 1, 2, or 3 heifers in the high energy or medium energy groups on adequate protein. It should also be noted that only one heifer on the low level of energy had shown heat by 90 days post-calving. Low level of energy thus had a more marked effect on reproductive performance. However, low protein level also appeared to delay the onset of heat.

TABLE 30.—ACTUAL AND ESTIMATED DAILY TDN INTAKE IN POUNDS BY LOTS IN PASTURE AND IN DRY LOT BY MONTHS

TDN INTAKE	TDN EST. GROUP I	TDN EST. GROUP II	TDN EST. GROUP III	TDN EST. GROUP IV
December	8.0	8.0	9.0	9.0
January, February	4.5	6.0	12.0	11.0
March	8.0	8.0	14.0	14.0
April, May, June	16.6	15.0	16.6	16.6
July, August	14.0	16.0	16.0	14.0
September, October, November	10.0	9.0	9.0	10.0

Source: Reynolds *et al.*, 1964.

Group I Pasture only (cows receive no supplementary feed).
Group II These cows are on dry lot and fed to equal weight gains of Group I.
Group III These cows are fed N.R.C. recommendations (9 lb. of TDN while dry, 16 lb. TDN while lactating).
Group IV These cows are on pasture and are fed when necessary to make weight gains equal to cows in Group III.

The application of information gained in dry lot to pasture conditions is difficult. An experiment has been conducted at the Iberia Livestock Station, Jeanerette, Louisiana. An attempt was made to increase reproductive performance by supplementing pasture. Angus heifers were bred as yearlings and divided into 4 groups. These were: group I receiving pasture only, group II in dry lot fed to make comparable gains to the group on pasture, group III in dry lot receiving the level of TDN recommended by the National Research Council (N.R.C.), and group IV on pasture supplemented so that gains were equal to those in the dry lot on the N.R.C. level of feed. The main periods of supplementation on pasture were January, February, and March (Table 30).

Reproductive performance was markedly improved by pasture

supplementation. The number of cows pregnant by the 22nd, 43rd, and 100th day of the breeding season was 1, 1, and 7 for the pasture only group and 5, 6, and 9 for the supplemented group on pasture (Table 31). Comparable reproductive performance was noted in the groups in dry lot.

TABLE 31.—PASTURE SUPPLEMENTATION AND REPRODUCTIVE PERFORMANCE IN LOUISIANA

GROUP	GROUP NO.	NO. LACTATING COWS	NO. COWS PREGNANT: 22ND DAY OF BREEDING SEASON	NO. COWS PREGNANT: 43RD DAY OF BREEDING SEASON	NO. COWS PREGNANT: 100TH DAY OF BREEDING SEASON	SETTLED FIRST SERVICE
						%
Pasture only	I	13	1	1	7	45
Dry lot (equal gains to pasture)	II	12	0	0	6	36
Dry lot (N.R.C. recommendations)	III	13	0	5	11	62
Pasture (supplemented)	IV	11	5	6	9	73

Source: Reynolds *et al.*, 1964.
For definition of Groups, see Table 30.

The poor reproductive performance in groups I and II were a result of a poor conception rate at first service and a delay in the onset of heat after calving. Conception rate was 45 and 36 per cent for groups I and II compared to 62 and 73 per cent in groups III and IV. The delay in onset of heat can be seen by noting results in Table 32. Twenty-three per cent and 15 per cent of the cows in groups I and II had shown heat by June 1 compared to 85 and 75 per cent in groups III and IV.

TABLE 32.—PERCENTAGE OF COWS IN EACH LOT SHOWING HEAT BY VARIOUS DATES

PERCENT COWS SHOWING HEAT BY:	GROUP I	GROUP II	GROUP III	GROUP IV
June 1, 1962	23	15	85	75
July 1, 1962	75	69	100	75
August 1, 1962	92	92	100	100

Source: Reynolds *et al.*, 1964.
For definition of Groups, see Table 30.

The results indicate that nutritional levels supplied by pasture in Louisiana do not support adequate reproductive performance. The reproductive performance can be improved by supplementing pasture at critical periods.

SUMMARY

Reproductive performance of a beef cow herd is affected markedly by nutritional level. Results presented show that age at first heat is dependent on level of energy fed either during the first winter or from weaning to first heat. Low levels of protein may also delay first heat but this appears to be the result of decreasing the appetite and thus decreasing the amount of feed the heifers eat. Level of energy fed following calving has a marked influence on reproductive performance. Cows gaining weight rapidly had the best reproductive performance. This occurred because more cows were in heat and bred early in the breeding season and more cows conceived on first service. Supplementation of pastures in Louisiana during critical periods improved reproductive performance markedly.

8

J. F. HENTGES, JR.

Minerals and Vitamins

The term reproduction includes the physiological mechanisms in the male for spermatogenesis, libido, mating, and fertility plus the analogous mechanisms in the female for ovigenesis, estrus, ovulation, conception, fetus development, and parturition. Reproduction is largely the result of coordinated function by the hormonal system, the reproductive organs, and general tissue health. Proof that minerals and vitamins are needed for the numerous coordinated events which comprise reproduction is found in the fact that cattle feed must contain a balanced combination of several mineral elements and vitamins along with nitrogenous and energy-producing feeds for good health and proper functioning of the endocrine and reproductive systems.

Little is known about the exact daily requirements and the proper balance of mineral elements and vitamins for diets of breeding beef cattle. Many factors affect the need of cattle for minerals and vitamins.

The environment (climate, shelter, soil, plants, etc.) with its differing degrees of stress, varies the need for supplementation of the natural diet with minerals and vitamins. For example, bulls and cows grazing Gulf Coast pastures in the hot, humid summer months have different requirements for food nutrients to maintain general health and comfort than similar cattle in a moderate, comfortable environment. Breeding cattle in different regions have different needs for supplements of feed nutrients in addition to those obtained from pasture because of seasonal differences in availability of growing forage. For example, cattle which enjoy long, almost year-around grazing seasons in rela-

tively frost-free regions may derive adequate carotenoids (provitamin A) from their natural diet while cattle on annually frosted and drought-stricken pastures may need a supplemental source of provitamin A (feed carotenoids) or synthetic vitamin A. In some regions, cattle on different parts of the same ranch have different nutrient requirements. For example, breeding cattle grazing pastures on organic muckland soils have a different need for supplemental copper than similar cattle grazing pastures on inorganic mineral (sandy) soils. A high content of molybdenum and associated elements in muckland pasture plants prevents the complete utilization of copper, thereby necessitating the addition to the diet (or by drench and/or implant) of relatively large quantities of supplemental copper.

Mineral elements and vitamins are involved in many reactions within the body tissues, namely: (1) conversion of food carbohydrates, protein and lipids to muscular work, growth and tissue fat; (2) regulation of osmotic pressure in body fluids and tissues (blood, urine, etc.); (3) maintenance of acid-base equilibrium in body tissues; (4) skeleton formation; (5) blood transport of oxygen and carbon dioxide during respiration; and (6) other reactions. Therefore, in doing cattle reproduction research and in reviewing published research reports to obtain information that can be put into practice on a beef cattle ranch, one should not think in terms of individual mineral elements or vitamins but should consider the quantity of each nutrient and the balance of all nutrients which are needed in the diet plus the demands of the environment upon the requirements of cattle for nutrients.

The foregoing statements imply that a discussion of the role of individual mineral elements or vitamins in cattle reproduction is sure to lead to the conclusion that these nutrients are simply "a few of the cogs in the complex metabolic machinery" that keep cattle functioning in whatever environment is provided by man.

Adequacy of Natural Diets

The worldwide literature relating soil deficiencies of mineral elements to livestock nutrition was reviewed by Beeson (1941, 1958) and Schutte (1964). Numerous researchers in the southern half of the United States have correlated soil and forage content of phosphorus, cobalt, copper, molybdenum and iron to cattle

performance and/or consumption of mineral supplements (Becker *et al.*, 1931; Stanley and Hodgson, 1938; Knox *et al.*, 1941; Nelson *et al.*, 1955). On white and gray sandy loam and fine sand soils in Florida, Becker *et al.* (1946, 1965) showed a relationship between nutritional anemia, locally termed "salt sick" in cattle, and a low content of copper, iron, and cobalt in forages and soils. On fine sand soils of south Texas, Black *et al.* (1958) and Reynolds *et al.* (1953) observed that a low content of soil and forage phosphorous was responsible for phosphorus deficiency locally termed "creeps" in range cattle. On muck and peat soils in Florida, Kidder (1941) and Davis *et al.* (1946) related excessive soil and forage molybdenum to a copper deficiency locally called "paces" in cattle. In the northern half of the United States, "goiter areas" are found wherever soils and water are low in iodine content (Huffman, 1947). "Alkali disease" or "blind staggers" in cattle has occurred where the soil and forage content of selenium was excessive (Dinkel, 1957).

While the earliest reports of mineral deficiencies in cattle contained descriptions of extreme abnormalities, some of which may have occurred only after several generations on the deficient forage, the predominant deficiencies in the middle of the 20th century are "borderline," often not recognized except upon study of production records.

Is it possible to estimate the nutrient adequacy of pasture forage for gestating and/or lactating beef cows by looking at the pasture?—or even by studying the results of chemical analyses of forage samples for crude protein, gross energy, crude fiber, ether extract, mineral elements, and vitamins? Although one may know the chemical composition of samples of pasture forage and have had previous experience with cattle on the pasture in question, accurate answers to these questions are complicated by two factors: (1) the difficulty of obtaining samples of pasture forage which are identical with what the average cow selects in grazing and (2) the necessity of estimating the amount of forage that the average cow will consume (voluntary feed intake).

Researchers have shown that voluntary feed intake is largest with forages having a low fiber and a relatively high protein content; therefore, chemical analyses of pasture forage samples are useful but may not fully indicate whether the forage will provide an adequate diet. The amount of forage voluntarily consumed is of paramount importance but a practical routine analy-

sis of forage for prediction of voluntary intake has not been developed.

Chemical analyses of forages are of value for detection of forages with a content of phosphorus, copper, cobalt, or carotenoids which is grossly deficient or with a content of molybdenum, selenium, or fluorine which is so high that deficiencies or toxicities are a certainty to develop (See Table 33).

Cattle dislike drinking water which contains more than 1000 parts per million of minerals. In regions where the only source of drinking water is highly mineralized (chlorides, carbonates, sulfates, and bicarbonates), cattle gradually will acquire a tolerance for the highly mineralized water but their production may be restricted. For example, in areas adjoining mines, an excessive intake of fluorine in drinking water has caused accumulations of fluorine in the tissues of the body and lowered production (Hobbs and Merriman, 1962; Merriman and Hobbs, 1962). Cattle in brackish coastal water areas are reported to avoid voluntary consumption of needed mineral supplements offered in mineral feeders because of the high saline content of their drinking water (Becker *et al.*, 1953). Because the mineral content of drinking water contributes materially to the dietary needs of cattle for mineral elements, it is as important to obtain chemical analyses on drinking water as it is on pasture forage. Even in cases where the mineral and vitamin content of both the pasture forage and drinking water is known, the adequacy of diets on beef cattle ranches must be partially evaluated by the physical condition (appearance) of the cattle.

deficiency, insecticide ingestion, etc.) which affects the central nervous system. Abnormal skeletal formation may reflect an inherent weakness prevalent in some bloodlines or a nutrient deficiency during the formation of the skeleton. Only by studying the ranch conditions and reports from diagnostic laboratories on blood levels, liver reserves, post-mortem pathology, parasite counts, pedigrees, etc., can one pinpoint the cause of poor physical condition in a cow herd.

The foregoing comments lead to the conclusion that a ranch manager's decision to increase the calf crop by expenditure of money for fertilizer or supplemental feeds should be based on something more reliable than appearance of the cows or appearance of the pasture forage. Methods have been reported for the diagnosis of mineral element or vitamin deficiencies suspected of being primary causes of poor physical condition associated with low fertility. These diagnostic methods include: (1) *analyses of blood samples* for hemoglobin, hematocrit (packed cell volume), phosphorus, calcium, magnesium, potassium, copper, vitamin A, and carotenoids; (2) *analyses of liver samples* taken by biopsy for copper, cobalt, iron, and vitamin A; (3) *analyses of bone* for fluorine, calcium and phosphorus; (4) *analyses of forage samples* for carotenoid and mineral element content; (5) *analyses of soils* for limestone, phosphorus, cobalt, copper, iron, and molybdenum; (6) *analyses of water* for solids and mineral content.

The mean expected levels of mineral elements in blood, liver, and bone of apparently normal cattle have been reported by Cunha *et al.* (1964), Chapman and Kidder (1964), Underwood (1962), Maynard and Loosli (1962), Nelson *et al.* (1955), Long *et al.* (1952), Watkins and Knox (1948), and Hobbs and Merriman (1962). Table 33 gives forage, blood, and liver levels of mineral elements which may be used as a guide for detecting deficiencies.

Mineral and Vitamin Requirements for Reproduction

It is of practical importance to know that all deficiency conditions seen in cattle are "relative deficiencies" involving more than one nutrient. Because of this and the fact that infertility may result from non-nutritional causes, scientists have experienced difficulty in determining the exact dietary nutrient requirements of cattle for reproduction. In a review of literature on the relation

of nutrition to endocrine-reproductive functions, Meites (1953) stated that almost all dietary factors had been claimed to be essential for reproduction at one time or another but only a few, mainly those involved in appetite regulation, had conclusively been shown to be needed. He reported that research prior to 1953 on the need of mineral elements for reproduction in cattle was complicated by a lack of appetite and low protein intake. Salis-

TABLE 33.—GUIDELINES FOR DETECTING DEFICIENCIES: LEVELS SHOWN OR HIGHER LEVELS INDICATE NORMALCY. LOWER LEVELS INDICATE DEFICIENT STATUS

	DRY FORAGE	BLOOD (PER 100 ML.)	DRY LIVER
Phosphorus	0.3%*	4 mg. (cow) 7 mg. (calf)	—
Copper	5 p.p.m.†	75 mcg.	75 p.p.m.
Cobalt	0.1 p.p.m‡	—	0.1 p.p.m.
Vitamin A	None	20 mcg.	30 mcg./gm.
β, Carotene	Variable 20 mg./lb.§	70 mcg.	—

Becker *et al.*, 1931; Theiler and Green, 1931; Eckles *et al.*, 1935; Palmer *et al.*, *1941*; *Knox et al.*, *1941*; Reynolds *et al.*, 1953; Nelson *et al.*, 1955) about phosphorus deficient cattle have described starving animals, abnormal estrous cycles and low rates of reproduction. It is difficult to separate the effects of a lack of protein, energy, phosphorus, and perhaps other nutrients in these reports. All reported that supplemental phosphorus increased the rate of reproduction whether administered in drinking water as a free choice supplement in a box, as phosphate-fertilized grass or in a concentrate feed mixture. The phosphorus content of pasture plants decreases with maturity; hence, the supplemental feeding of a phosphorus source, preferably defluorinated phosphate, dicalcium phosphate, or other disease-free inorganic source, has become an accepted practice. The daily requirement of mature 1,000- to 1,200-pound lactating cows for phosphorus is 8-10 grams for maintenance, an additional 7 grams during the last trimester of pregnancy, plus 0.7 gram for each pound of milk being produced (N.R.C., 1958). The daily requirement of moderately active bulls for growth and maintenance varies from 15 grams for 1,000 pound bulls to 18 grams for 1,800 pound bulls (N.R.C., 1963).

Calcium and magnesium are closely associated with phosphorus in metabolism but both are abundant in forages; therefore, it is unlikely that dietary deficiencies would occur in breeding cattle on improved pastures. It is more likely that an excessive ratio of calcium plus magnesium to phosphorus might exist and adversely affect production. Grass tetany, a disease of cattle and calves grazing lush pastures in the spring, has been characterized by a low blood magnesium content. The literature on this complex disease was reviewed by Barnett and Reid (1961) and Fontenot *et al.* (1965).

Deficiencies of copper and cobalt have been reported to delay sexual maturity in heifers and to inhibit reproduction (Becker *et al.*, 1931; Bennets *et al.*, 1941; Becker *et al.*, 1946; Bennets *et al.*, 1948; Allcroft and Parker, 1949). Undoubtedly the anemia, diarrhea, and weight loss caused by a dietary deficiency of these mineral elements has a greater adversity on reproduction than is recorded in the literature. The role of copper and cobalt in ruminant nutrition has been reviewed by Davis *et al.* (1946), Marston (1952), Dye and O'Harra (1959), Underwood (1962), and Chapman and Kidder (1964). Extreme deficiencies of copper

and cobalt occur in the soils and plants of numerous areas throughout the world. In addition, a high molybdenum content in plants grown on peat or muck soils is associated with some factor that can accentuate a copper deficiency in cattle (Kidder, 1941). Of interest is a report by Huber *et al.* (1965) that diets containing 100 p.p.m. of molybdenum and a low copper content were not toxic and resulted only in slight decreases in liver copper after being fed to cows for six months. Apparently, the interrelationship of molybdenum, copper, and sulfur is more complex than previously thought. It is recommended (Chapman and Kidder, 1964) in Florida that mineral mixtures which are offered to range cattle have a minimal copper content of 0.75 per cent on organic peat or muck soils and 0.15 per cent on sandy inorganic soils. The cobalt content of such mixtures should be 0.03 per cent on either type of soil. While a deficiency of iron is difficult to demonstrate except on deep, white sandy soils (Becker *et al.*, 1965) it is recommended that a source of iron, preferably ferrous sulfate, be included in mineral supplements because of its interrelated role with copper and cobalt in blood composition. Because most cattlemen have always associated a red color with mineralized feeds, the addition of red-colored but relatively insoluble iron oxide to mineral mixtures may continue to be a practice of feed manufacturers.

The necessity of manganese for reproduction has been more firmly established with monogastric animals than with ruminants. Bentley and Phillips (1951), Grashius (1957), and Meyer and Engelbertz (1960) have related lowered fertility in cows and heifers to manganese deficiencies as predicted from diet, ovary or hair content of manganese. Because almost all improved pasture forages and concentrate feed ingredients contain more than 10 p.p.m. manganese, a deficiency of this essential mineral element in grazing cattle is not likely to be encountered. For assurance, manganese compounds have become standard ingredients in commercial trace mineralized salt in the United States.

The feeding of supplemental zinc to mature cattle has been reported to increase milk production and aid reproduction in Finland (Haarinen and Hyppula, 1961). The level of zinc in most Bermuda grass pastures in the Piedmont and Coastal Plain regions of the U.S.A. are adequate for reproduction in cattle (Miller and Miller, 1963). It is customary in the U.S.A. to include a source of zinc in trace mineralized salt mixture.

The role of iodine as a dietary essential mineral element for cattle reproduction is definitely linked to its presence in thyroxine, a hormone secreted by the thyroid gland. A dietary deficiency of iodine has been reported to cause the birth of dead calves, retention of the placenta (afterbirth), decline in sex drive in bulls, and lack of estrus (heat) in cows (Schutte, 1964). Stabilized iodine is included as a standard ingredient in commercial trace mineralized salt in the United States.

Fluorine, instead of being added to the diet for cattle, is most often found in excess in the natural diet and is reported to be toxic when consumed in excessive amounts over long periods of time. More than 3 p.p.m. in dry pasture forage or 5 p.p.m. in drinking water is excessive for grazing cattle. Deleterious effects of fluorine on milk production, skeletal structure, and reproduction in cattle was reported by Phillips *et al.* (1934), Suttie *et al.* (1957), and Hobbs and Merriman, (1962). Precaution should be taken to avoid forcing breeding cattle to consume water, forage, limestone, or phosphates which have an excessive fluoride content.

From the time that a calf starts to ruminate and "chew its cud," it can be assumed that microbial (bacteria and protozoa) synthesis in the forestomach will provide an adequate supply of the B-complex vitamins. Extensive research by Kon and Porter (1954) and Porter (1961) showed that the synthesizing capacity of the rumen microorganisms was sufficient to keep a constant level of B-complex vitamins in the rumen contents of steers regardless of the vitamin content of the diet.

Healthy mature cattle have not been found to have a dietary requirement for vitamin C because of their ability to synthesize enough to meet their requirement. Phillips (1940) and Phillips *et al.* (1941) reported partial success in the use of vitamin C (ascorbic acid) for the improvement of fertility in repeat-breeder cows and slow-breeding bulls. Others (Asdell, 1949) were unable to confirm these findings; consequently, the current belief is that cattle are able to synthesize adequate quantities of vitamin C to meet their needs for reproduction. Further research with vitamin C is warranted, especially in unfavorable environments which exert considerable climatic and emotional stress on range breeding herds.

Of the fat-soluble vitamins, A, D, E, and K, the one most

closely linked with reproduction in cattle is vitamin A. Deficiencies of vitamin A, termed "avitaminosis A", have been reported to cause serious disturbances in fetal development resulting in dead, weak, or malformed calves. Vitamin A deficient cows have been observed to have keratinization of the vaginal epithelium, retained placentas, and delayed conception. Vitamin A deficient bulls have been reported to exhibit delayed puberty, testicular tissue degeneration, and pituitary cysts. The time required to deplete normal liver reserves of vitamin A has been reported to vary from 10 to 206 days in calves (Riggs, 1940) and up to 350 days in cows (Wheeler *et al.*, 1957). The literature on the role of vitamin A in cattle reproduction was reviewed by Davis and Madsen (1941), Ronning *et al.* (1953), and Parrish (1961). The minimum daily requirement for vitamin A by lactating beef cows was raised recently to 42,000 International Units (N.R.C., 1963). This is twice the amount required by gestating cows. Moderately active 1,000- to 1,800-pound bulls require about 30,000 to 40,000 I.U. depending on weight.

The role of vitamin E is not understood but is believed to involve the antioxidant properties of tissues in association with selenium, sulfur, and other elements. Claims that vitamin E supplements aided reproduction have not been supported by research with cattle. Healthy cattle grazing green forage plants apparently acquire an adequate supply of vitamin E for reproduction. The effect of stress and endocrine imbalance upon vitamin E requirements of cattle is not known. The literature on vitamin E in health and disease of cattle was reviewed by Blaxter (1962).

Vitamin K is synthesized by bacteria in the forestomach of cattle in quantities sufficient for normal blood clotting; hence, a need for supplemental vitamin K by healthy cattle has not been reported.

ENVIRONMENT DEMANDS UPON REQUIREMENTS

The requirement for minerals, vitamins, and other nutrients in the diet of cattle is largely determined by the level of hormones in the blood. The rate of secretion of these hormones by the endocrine glands may be altered by environmental factors, especially climate. Changes in weather, which include temperature, relative humidity, air motion, light, and radiation have a marked effect upon pasture plants which make up most of the natural diet of cattle and also directly regulate cattle comfort (or discomfort). The extensive literature on this subject was reviewed by Hammond (1954), Brody (1955), Andrews (1957), Dutt (1960), and Hafez (1962).

In hot, humid climates, breed differences may be correlated with differences in weight gain, milk production, and rate of reproduction (Cunha, *et al.*, 1963). Breeds of *Bos indicus* origin are reported to be more heat-tolerant (Brody, 1955), to graze more frequently during the day (Rhoad, 1955), to produce more milk (Cunha, *et al.*, 1963), to have a lower incidence of estrus and conception during lactation (Howes *et al.*, 1963), and to have a higher daily requirement for nutrients than breeds of *Bos taurus* origin. It has been recommended that the heavy milk producing breeds of *Bos indicus* origin be provided minerals, vitamins, and other nutrients in accord with the National Research Council minimum requirements for dairy cattle (N.R.C., 1958). Otherwise, lactating cows of these breeds may fail to become pregnant during the usual limited 90- to 120-day breeding season.

The plane of nutrition plays an apparent role in susceptibility of bulls to heat stress and spermatogenesis. Bulls in hot, humid climates exert more physical effort in seeking out and serving cows, both activities resulting in the following physiological effects: elevation of body temperature, need for sperm replenishment, probable reduction in endocrine and metabolic activity to lessen the heat dissipation load, probable reduction in forage intake, and reduced fertility if the natural diet is not fortified with minerals, vitamins, and proteins. When yearling and two-year-old bulls are pasture mated, a dual need exists for nutrients to continue growth and to permit reproduction. Because data are not available to substantiate these observations, there is a need for a systematic investigation of the quantitative nu-

tritional requirements of breeding beef cattle under controlled environmental conditions, especially those involving a hot, humid climate and a low quality forage diet. The need of such research is increasing in importance because of the changing geography of beef cattle production toward tropical and semi-tropical environments where soil nutrients are leached during a rainy season causing the mineral and perhaps vitamin content of forages to be inadequate for breeding cattle diets.

9

W. C. McCORMICK

Breeding of Cow and Plane of Nutrition

Both breeding of animals and level of nutrition affect reproduction. Most of the information in this report is the result of direct experimentation on the effects of nutrition on breeding. Some data have been adapted from other studies. In the final analysis per cent calf crop weaned is the best economic indicator of reproduction and, as used in this report, is the number of calves weaned as based on cows exposed. Per cent stillborns or deaths are based on calves born.

Effects of Breeds and Systems of Breeding

A part of our research involves studying grading-up, crisscrossing, and rotational crossing as breeding systems for commercial beef production. The study is conducted at the State Prison at Reidsville, Georgia, where the cattle are maintained under commercial cattle production conditions. Grade Angus, Hereford, and Santa Gertrudis are used in grading-up. The three possible crisscrosses between these breeds and a rotational cross (made up of equal numbers of each crisscross) were also maintained as contemporaries. The three grade and three crisscross herds contained about 40 cows each while the rotational herd contained 60 cows. A total of around 300 females were bred over a period of 8 years to supply information on foundation animals. Foundation animals in the crisscross herds were first crosses themselves. The animals in the rotational herd were first crosses being mated to the third breed. As generation one replacements became available, foundation animals were replaced. Data for

TABLE 34.—GRADING-UP, CRISSCROSSING AND ROTATIONAL CROSSING AS BREEDING SYSTEMS FOR COMMERCIAL BEEF PRODUCTION

Breeding group	Number exposed	Number born	% Calf crop	No. stillborn M	No. stillborn F	No. stillborn Total	No. died M	No. died F	No. died Total	Number weaned	Per cent stillborn	Per cent died	Per cent calf crop weaned
Foundation cows													
Gr. A*	214	191†	89.3	4	3	7	3	0	3	181	3.66	1.57	84.6
Gr. H*	216	189*	87.5	2	1	3	0	4	4	182	1.39	2.12	84.3
Gr. SG*	196	177	90.3	5	2	7	4	2	6	164	3.95	3.39	83.7
AxH	209	192	91.9	3	1	4	3	2	5	183	2.08	2.60	87.6
AxSG	182	161†	88.5	4	3	7	2	1	3	151	4.35	1.86	83.0
HxSG	200	182‡	91.0	0	2	2	2	1	3	177	1.10	1.65	88.5
AxHxSG	302	275‡	91.1	3	2	5	1	1	2	268	1.82	0.73	88.7
Total	1519	1367	90.0	21	14	35	15	11	26	1306	2.56	1.90	86.0
Grades	626	557	89.0	11	6	17	7	6	13	527	3.05	2.33	84.2
Crossbreds	893	810	90.7	10	8	18	8	5	13	779	2.22	1.60	87.2
Generation One Cows													
Gr. A	80	71	88.8	0	1	1	2	0	2	68	1.41	2.82	85.0
Gr. H	98	91	92.9	2	1	3	0	0	0	88	3.30	0.00	89.8
Gr. SG	89	74	83.1	1	2	3	1	1	2	69	4.05	2.70	77.5
AxH	95	89	93.7	4	0	4	0	0	0	85	4.49	0.00	89.5
AxSG	89	81	91.0	1	4	5	1	1	2	74	6.17	2.47	83.1
HxSG	94	88*	93.6	1	1	2	1	0	1	85	2.27	1.12	90.4
AxHxSG	127	113	89.0	4	0	4	3	0	3	106	3.54	2.65	83.5
Total	672	607	90.3	13	9	22	8	2	10	575	3.62	1.65	85.6
Grades	267	236	88.4	3	4	7	3	1	4	225	2.97	1.69	84.3
Crossbreds	405	371	91.6	10	5	15	5	1	6	350	4.04	1.62	86.4

*One, †Two, ‡Three pairs of twins
A=Angus, H=Hereford, SG=Santa Gertrudis

TABLE 35.—EFFECT OF BREEDING AND PLANE OF NUTRITION ON REPRODUCTIVE DATA OF COWS

Group	No. Exposures	No. Born	Per cent Calf Crop Born	No. Stillborn M	No. Stillborn F	No. Stillborn Total	No. Died M	No. Died F	No. Died Total	No. Weaned	Per cent Stillborn	Per cent Died	Per cent Calf Crop Weaned
Grade Hereford	188	141	75.0	2	1	3	3	1	4	134	2.1	2.8	71.3
Brahman Cross	272	227	83.4	0	2	2	1	1	2	221	0.9	0.9	81.3
High Low Plane	223	183	82.0	0	2	2	2	1	3	178	1.1	1.6	79.8
Low Plane	173	123	71.1	0	1	1	2	1	3	119	0.8	2.4	68.8

TABLE 36.—EFFECTS OF FEEDING FOR FAST GAINS ON FERTILITY OF BULLS

Year	Breed	No. Bulls	Weaned Weight	Daily Gain	Weight/ Day of Age	Final Age	Condition Score	Breeding Efficiency*
1958	Angus	2	473	2.63	2.29	394	11.4	48- 43- 90
1958	Polled Hereford	7	501	2.74	2.33	401	11.6	164-141- 86
Average			489	2.68	2.31	397	11.5	88
1959	Angus	2	403	3.04	2.39	365	11.8	42- 37- 88
1959	Polled Hereford	7	491	3.08	2.49	384	11.6	162-144- 89
Average			447	3.06	2.44	375	11.5	89
1960	Angus	3	501	2.38	2.37	380	12.1	78- 71- 91
1960	Polled Hereford	7	550	2.67	2.53	394	11.7	177-165- 93
Average			525	2.53	2.45	387	11.9	92
1961	Angus	2	486	2.65	2.52	370	12.2	47- 47-100
1961	Polled Hereford	8	503	2.74	2.58	374	11.7	193-183- 95
Average			495	2.70	2.55	372	11.9	97
1962	Angus	4	464	2.84	2.43	388	10.0	85- 60- 71
1962	Polled Hereford	8	503	3.19	2.66	391	10.1	194-180- 93
Average			484	3.01	2.55	390	10.0	82
All Angus		13	468	2.70	2.40	380	11.3	300-258- 86
All polled Hereford		38	509	2.89	2.52	388	11.3	890-813- 91
All bulls		51	489	2.80	2.46	381	11.3	1190-1071-90

*Cows exposed, calves born, and per cent calf crop, respectively.

Cattlemen should not feed excessively during winter since such a practice is costly and breeding performance is not likely to be improved. The cows should be fed adequately. A reduction in amount fed during winter results in reduced calf crops. The cows should be wintered in good enough condition to breed back in the spring.

EFFECTS OF FEEDING FOR FAST GAINS ON FERTILITY OF BULLS

Some reports have indicated that feeding high concentrate rations to bulls to obtain rapid gains affects semen quality and ultimately impairs fertility. The Georgia Coastal Plain Experiment Station has operated a Test Station for the past 7 years. During this time, a ground mixed ration containing around 12 per cent crude protein and approximately 64 per cent concentrates has been full fed. Station owned Angus and Polled Hereford bulls have been fed along with Test Station animals. Feeding was started the day of weaning and continued for 168 days. From 1958 through 1962, 51 bulls fed in the Test Station were used. Records of these animals are shown in Table 36 by breed and year.

The bulls were removed from test at around 13 months of age. Six were bred immediately thereafter as yearlings; the remainder was bred first as two-year-olds. Total gain for the animals as indicated by weight-per-day-of-age tended to increase with years. Condition score (10, 11, and 12 = good, good plus, and low choice, respectively) tended to at least remain constant during the first 4 years; scores dropped during the last year. This drop was due to a tendency of the scorers to score the animals as bulls, whereas in former years the animals were considered as steers. Apparently feeding for rapid gains for 168 days as described above did not impair the breeding efficiency to any noticeable extent of young bulls bred either as yearlings or two-year-olds. One bull was sterile; however, it is not believed that feeding was the primary cause of sterility.

EFFECT OF GRAZING WINTER PASTURE ON BIRTHWEIGHT

For a period of 3 years, studies were conducted comparing the grazing of small grain pasture 4 hours daily plus the feeding of around 6 pounds hay per cow daily with full feeding hay plus

1 to 2 pounds cottonseed meal per cow daily. Experimental animals were cows bred to calve in January, February, and March. The cows were placed on grazing just prior to the onset of calving (December 15 to January 8). The cows on pasture gave birth to calves weighing 5 to 7 pounds or around 10 per cent more than those fed hay and cottonseed meal (Table 37).

Good strong heavy calves at birth are desirable as long as extra weight does not interfere with normal parturition. Our

TABLE 37.—EFFECTS OF SMALL GRAIN PASTURE ON BIRTH WEIGHT OF CALF

YEAR	1961		1962		1963	
COWS FOR TREATMENT	33		24		20	
TREATMENTS	GRAZING	DRYLOT	GRAZING	DRYLOT	GRAZING	DRYLOT
Avg. daily ration (lbs.)	6.5	25.3	6.6	26.5	5.5	30.0
Hay	6.5	24.1	6.6	25.0	5.5	28.5
Grazing	*	—	*	—	*	—
Cottonseed meal	—	1.2	—	1.5	—	1.5
Avg. birthweight (lbs.)	81.7	75.8	74.0	69.0	81.2	74.0

*Cows permitted to graze oats or rye pasture 4 to 5 hours daily.

Angus and Polled Hereford heifers are bred to calve first as two-year-olds. We think it vitally important to feed and care well for heifers calving first as two-year-olds. In earlier years we wintered such heifers by grazing lush small grain pastures. The number of stillborn calves and cases of difficult births were unusually high so the practice of grazing was discontinued. It is believed that an increase in birthweights due to grazing small grain contributed to the calving problems and resulted in lowered per cent calf crop weaned.

In summary, these data indicate that (1) crossbreeding resulted in a 2-3 per cent greater calf crop, (2) a reduction of around 20-25 per cent in hay fed resulted in 10 per cent fewer calves, and (3) grazing small grain pastures resulted in 10 per cent heavier calves at birth, which in the case of heifers, especially, could result in a greater per cent of stillborns.

10

H. L. CHAPMAN, JR.

Blackstrap Molasses and Different Breeds

A major portion of the blackstrap molasses consumed in the United States goes into animal feed (Meade, 1964). Blackstrap molasses is rich in energy, containing 48 to 50 per cent total sugars and, in addition, having minerals, some protein, and a variable amount of vitamins. Reported to have 75 to 85 per cent the feeding value of corn grain, molasses is widely used in commercial feeds to increase palatability, decrease dustiness, and for its binding capacity. Considerable information is available (Chapman *et al.*, 1965, and Scott, 1953) concerning its use in cattle fattening.

During 1963, 25,000,000 gallons of blackstrap molasses were produced in south Florida. It has been estimated this will increase to 50,000,000 gallons by 1967, providing approximately 575,000,000 pounds of readily available carbohydrate-feed for use in livestock feeds. As mentioned, there are many published reports regarding the use of cane molasses for fattening cattle but little information is available regarding the use of blackstrap molasses as a supplement to pasture for beef cows. The purpose of this report is to present experimental data pertaining to feeding blackstrap molasses to beef cows of various breeds and to discuss the utilization of molasses in conjunction with pasture.

Definition of Molasses

Blackstrap molasses is a by-product of either raw cane sugar manufacturing or refining. It is the heavy, viscous liquid separated from the final low-grade massecuite from which no further

sugar can be crystallized by the usual methods (Meade, 1964). This product is viscous and in order to facilitate handling and for use in mixed feeds it is customarily diluted with water to approximately 79.5° Brix. The Association of American Feed Control Officials define this diluted product as cane molasses for feeding (Meade, 1964) and designate that it will contain 48 per cent or more total sugars as invert sugar. If its moisture content exceeds 27 per cent, its density may not be less than 79.5° Brix determined by double dilution (Crochet, 1965).

TABLE 38.—APPROXIMATE COMPOSITION OF BLACKSTRAP MOLASSES

COMPONENT	RANGE %
Water	17-25
Sugars	
Sucrose	30-40
Reducing sugars	10-25
Other carbohydrates	2- 5
Ash (K_2O, CaO, MgO, Na_2O, R_2O_3 (Fe), SO_3, Cl, P_2O_5, SiO_2 and insolubles)	7-15
Nitrogenous compounds	
Crude protein	2.5-4.5*
True protein	0.5-1.5
Unidentified nitrogenous compounds	1.5-3.0
Non-nitrogenous acids (Aconitic, citric, malic, oxalic, glycolic, succinic, fumaric, tartaric, mesaconic)	2.0-7.5
Waxes, sterols, phosphalids	0.1-1.0
Vitamins	Variable

Source: Meade (1964)

*Blackstrap molasses produced on organic soil will contain 7 to 10 per cent crude protein (Table 40)

TABLE 39.—EXPERIMENTAL DESIGN*

EXPERIMENTAL TREATMENT	BREED OF SIRES		
	ANGUS	BRAHMAN	HEREFORD
Control (no molasses)	A AB AH	B BA BH	H HA BH
Seasonal (winter-fed)	A AB AH	B BA BH	H HA BH
Continuous-fed	A AB AH	B BA BH	H HA BA

*Letters in table refer to breed composition of cows bred to each sire. A=Angus; B=Brahman; H=Hereford; BH=Braman x Hereford; BA= Brahman x Angus; and AH=Angus x Hereford.

EXPERIMENTAL PROCEDURE

Approximately 300 head of cows were divided into three equal groups on the basis of age, breed, and relative potential production. The majority of the cows were one to two years old when placed on the study and, with the exception of some purebred cows, were purchased from commercial herds in south Florida. The groups were randomly allotted to experimental treatments of no molasses, seasonally-fed molasses, and continuously-fed molasses for 3 1/2 years (Table 39). The seasonally-fed molasses was provided for 4 winters. The molasses used was heavy mill-

TABLE 40.—CRUDE PROTEIN, °BRIX AND ASH CONTENT OF COMPOSITE SAMPLES OF BLACKSTRAP MOLASSES

SAMPLE NUMBER	CRUDE PROTEIN (%)	°BRIX	ASH (%)
1	8.6	85.1	7.9
2	7.1	86.1	8.0
3	7.3	85.0	8.6
4	8.1	86.2	8.3
5	10.1	84.4	7.9
6	9.0	86.4	8.8
7	9.7	85.1	8.3
Average	8.6	85.5	8.2

run blackstrap molasses (85 to 88° Brix) produced on organic soil. (Blackstrap molasses used in this experiment was furnished by the United States Sugar Corporation, Clewiston, Florida.) It was fed twice weekly to furnish an average intake of 5 pounds per cow daily. During summer months the continuously-fed group would not consume 5 pounds a day and when this occurred the cattle were provided free access to molasses not to exceed the 5 pound rate of intake. The seasonally-fed group received molasses from approximately the first of December until the middle of April of each year. A complete mineral mixture was fed free-choice to all cows.

The breeding season was from January 15 to April 15 each year. Single sire herds were used with 1/3 of the cows in each molasses treatment bred to an Angus, Hereford or Brahman bull (Table 39). The approximately 300 cows were maintained on 180 acres of Roselawn St. Augustine grass pasture which was divided into 9 separate pastures. The groups were rotated every 2 weeks to minimize the effect of pasture differences on animal performance. The sires were rotated annually within breed of sire over each of the molasses treatments to minimize sire differences. The cows were pregnancy tested 60 to 90 days after the bulls were removed and with one exception all open cows were sold. It was not possible to remove all open cows from the Brahmans receiving no molasses without reducing inventory. These cows were allowed one open year and if open 2 consecutive years they were culled. Herd replacements were made in June of each year.

Measurements taken included quarterly weights, pregnancy, calving, and weaning dates for the cows and birth and weaning weight for the calves. Monthly forage samples were obtained for proximate analysis. Molasses samples were obtained at delivery and analyzed for Brix, crude protein, and ash.

ranged from 18.5 to 49.3 per cent, crude protein from 9.58 to 17.21 per cent, crude fiber from 26.28 to 33.70 per cent, ether extract from 1.42 to 4.17 per cent, nitrogen-free extract from 41.37 to 52.11 per cent, and ash from 5.02 to 10.72 per cent. The crude protein content of the forage was below 10 per cent only once during the 32 months that samples were taken.

TABLE 41.—COMPOSITION OF ROSELAWN ST. AUGUSTINEGRASS*

	LOW	HIGH	AVERAGE†
Dry Matter	18.5	49.3	30.7
Crude protein	9.58	17.21	13.46
Crude fiber	26.28	33.70	30.08
Ether extract	1.42	4.17	2.54
Ash	5.02	10.72	7.43
Nitrogen free extract	41.37	52.11	46.49

*Crude protein, crude fiber, ether extract, ash and nitrogen-free extract are expressed as a per cent of dry matter.
†Each figure is an average of 32 months.

COW WEIGHTS

Molasses treatment did not have a significant effect on cow weights. The average initial cow weights were 827, 842, and 830 pounds respectively for the non-fed, seasonally-fed, and continuously-fed groups. While there was a trend toward increasing the size of cow in the continuously-fed group, the major effect of molasses supplementation on cow weights was that of reducing weight losses during the fall and winter months. Generally the three groups had returned to the same relative weight relationship by the following June. Quarterly weights are available in more detail (Chapman *et al.*, 1965).

RATE OF CONCEPTION

Molasses treatment and breed of cow had a highly significant effect upon conception rate as shown in Table 42. During the first year there was little difference in the conception rate between the three molasses treatments. This could have been due to the good condition of the cows and pasture during the first year or it could be that the benefit from supplemental feeding of brood cows is cumulative and takes time to express its full value. As the experiment progressed during the next three breeding seasons the cattle receiving no supplemental feed had conception

rates of 83.3, 88.3, and 81.7 per cent, as compared to 92.6, 93.3, and 95.8 per cent for seasonally-fed cattle and 94.8, 92.6, and 92.9 per cent for the continuously-fed cattle during the same three breeding seasons.

There were differences in the conception rate of various breeds due to the supplemental molasses. The primary difference was that the nonsupplemented Brahmans had a lower rate of con-

TABLE 42.—AVERAGE PERCENTAGE PREGNANCY RATE

	Molasses treatment*		
Breed	None	Seasonal	Continuous
A x A	90.6	93.2	90.2
B x B	63.0	78.6	91.8
H x H	92.7	98.1	94.5
A x BA	92.3	91.3	100.0
B x AB	70.0	100.0	96.3
A x HA	100.0	94.7	95.2
H x AH	91.2	97.6	95.2
B x HB	89.7	95.0	90.2
H x BH	87.5	97.1	97.2
Average	86.9	93.9	94.1

*Approximately equal numbers of cows were allotted to each molasses treatment for each classification.

ception than the Hereford or Angus cows on the same program. The Brahman x English crossbred cows had intermediate rates of conception, being higher than the purebred Brahman cows but lower than the Hereford, Angus, or Hereford x Angus cows when receiving no supplemental feed. Feeding molasses either seasonally or continuously tended to equalize breed differences except for the Brahman cows. The latter breed had an additional increase in rate of conception from continuous feeding not experienced by most of the other breeds. More detailed information concerning yearly performances of breeds is available (Chapman *et al.*, 1965).

CALF PRODUCTION

Supplemental molasses increased the calf survival rate after birth from 93.6 to 94.3 and 96.4 per cent as shown in Table 43. The differences were not statistically significant. The effect of molasses treatment on calf survival was variable for the various breed groups.

:ABLE 43.—AVERAGE PERCENTAGE CALF SURVIVAL FROM BIRTH TO WEANING

Breed	Molasses treatment		
	None	Seasonal	Continuous
A x A	88.6	89.8	92.9
B x B	91.7	92.9	97.1
H x H	91.2	100.0	97.8
A x BA	94.1	100.0	88.9
B x AB	90.9	88.9	88.9
A x HA	94.7	86.2	100.0
H x AH	96.0	97.1	97.1
B x HB	100.0	96.0	100.0
H x BH	100.0	100.0	100.0
Average	93.6	94.3	96.4

TABLE 44.—AVERAGE PER CENT CALVES WEANED PER COW ON INVENTORY

Breed	Molasses treatment		
	None	Seasonal	Continuous
A x A	84.8	88.0	88.6
B x B	62.9	83.9	89.5
H x H	91.2	100.0	97.8
A x BA	94.1	100.0	88.9
B x AB	83.3	88.9	88.9
A x HA	94.7	86.2	100.0
H x AH	96.0	97.1	97.1
B x HB	96.2	92.3	100.0
H x BH	100.0	100.0	100.0
Average	87.9	92.6	94.6

TABLE 45.—AVERAGE WEANING WEIGHTS (LBS.)

Breed	Molasses treatment		
	None	Seasonal	Continuous
A x A	302	339	358
B x B	302	337	346
H x H	340	369	376
A x BA	360	409	397
B x AB	382	406	394
A x HA	328	356	339
H x AH	332	366	365
B x HB	383	400	408
H x BH	375	401	412
Average	337	369	372

Each molasses feeding program increased weaning per cent (Table 44), with the seasonally-fed cows being intermediate between the group receiving no molasses and that having continuous access to molasses. The effect upon breed group was variable, the most evident benefit occurring in the purebred Brahmans.

At the end of each molasses treatment the weights of weaned calves were increased to 337, 369, and 372 pounds for the non-fed, seasonally-fed and continuously-fed groups, respectively. The effect of molasses was variable among breed groups (Table 45).

TABLE 46.—AVERAGE PRODUCTION PER COW (LBS. CALF WEANED ANNUALLY)

	Molasses treatment		
Breed	None	Seasonal	Continuous
A x A	256	298	317
B x B	190	283	310
H x H	310	369	368
A x BA	339	409	353
B x AB	318	361	350
A x HA	311	307	339
H x AH	319	355	354
B x HB	368	369	408
H x BH	375	401	412
Average	296	342	352

The average production per cow, in terms of pounds of calf weaned, is summarized in Table 46. Over the four year period the seasonally-fed cows had an average of 46 more pounds of calf produced per cow and the continuously-fed group 56 more pounds per cow. Here again it appeared that the effect was cumulative since there was more difference due to molasses treatment during the last two than during the first two years (Chapman *et al.*, 1965).

The greatest effect of molasses treatment upon pounds of calf weaned per cow was experienced by the Brahman, being increased 93 and 120 pounds by the seasonally-fed and continuously-fed programs. This is a direct reflection of improved reproduction as the effect on the weaning weights was not greatly different than with other breeds. Detailed yearly data by breed are available (Chapman *et al.*, 1965). An economic evaluation of the blackstrap molasses feeding programs is also available (Chapman *et al.*, 1965).

Discussion

In order to properly evaluate blackstrap molasses as a supplemental feed to pasture for beef cows it is necessary to consider the nutritional requirements of beef cattle, specifically what proportion of these requirements are furnished by pasture forage, and what portion can be provided by molasses.

Nutritional requirements of beef cows

Beef cows have a minimum nutritional requirement necessary to maintain normal body functions, even though the animal does not gain weight, produce a calf, or give milk. Many of these

Table 47.—Daily Total Digestible Nutrients, Digestible Protein, and Phosphorus Required by Pregnant and Nursing Cows

Body Weight (lbs.)	Average Daily Gain (lbs.)	TDN (lbs.)	Digestible Energy (therms)	Digestible Protein (lbs.)	Phosphorus (gm)
		Pregnant heifers			
700	1.5	10.0	20	0.9	14
900	0.8	9.0	18	0.8	12
1000	0.5	9.0	18	0.8	12
		Pregnant mature cows			
800	1.5	11.0	22	1.0	15
1000	0.4	9.0	18	0.8	12
1200	0.0	9.0	18	0.8	12
		Cows nursing calves, first 3 to 4 months after calving			
900					
1100	0.0	16.8	34	1.4	23

Source: National Academy of Science Publication 579.

nutritional needs can be furnished by pasture forage. After the nutritional requirements for body maintenance are provided, additional nutrients are needed for growth, for fattening, during pregnancy, or while nursing a calf.

The total digestible nutrient (TDN), digestible protein (DP), and phosphorus recommendations of the National Research Council (NRC) for the pregnant or lactating cows are presented in Table 47. These recommendations are considered to be the actual requirement of these type cattle and do not contain any so-called "safety factor." They are the minimum amount

that should be provided to cattle during these stages of their life cycle. It should be noted that the requirement for TDN and DP increases over 50 per cent and for phosphorus almost 100 per cent during the first 3 to 4 months after calving.

When the NRC recommendations for brood cows are corrected on the basis of per cent body weight, the DP requirement corresponds to approximately 0.15 per cent of the body weight of 900- to 1,100-pound cows during the three to four months after calving. Pregnant cows and heifers should receive daily about 0.1 per cent of their body weight as DP. The daily phosphorus requirement in grams for maintenance of cattle can generally be calculated by multiplying the body weight by 0.02.

Other nutrients that should be evaluated to determine if supplemental sources are needed include copper, cobalt, iron, and vitamin A. The need for these will vary but each are vital for growth and reproduction by beef cows. The exact copper requirements for all ages and kinds of beef cattle have not been well defined. However, beef cattle on organic soils should have an average daily intake of ⅛ gram of copper. The daily intake on inorganic soil can be approximately 20 per cent of this amount. The NRC reports the daily cobalt requirements of beef cattle to be in the range of 0.07 to 0.10 milligram per 100 pounds of body weight. The iron requirements of cattle are not known. It is an essential mineral for beef cattle, needed in the formation of hemoglobin and for certain other body functions. It appears that body iron may be re-used by the animal. Information is lacking regarding the absorption and utilization of iron from various compounds. Heavily parasitized cattle may respond to iron supplementation. Current NRC recommendations suggest 560 to 680 International Units (I. U.) of vitamin A per 100 pounds of body weight for growth; 1,200 to 1,600 I. U. per 100 pounds of weight during pregnancy; and 4,000 I. U. per 100 pounds during the first three to four months after calving. Recent experimental evidence indicates that present NRC recommendations are low in many cases. The cost of vitamin A is very small and cattle should generally be fed the maximum or even higher levels than the present NRC recommendations. Until more information is obtained a good "rule of thumb" is to feed at least 3,000 I. U. of vitamin A per 100 pounds of body weight daily, to cattle of any age, sex, or size where it is suspected that vitamin A supplementation may help.

NUTRITIONAL ADEQUACY OF PASTURES

The nutritional quality of pasture forage is affected by a number of factors, including soil type, forage variety, fertilization program, amount of grazing, season of the year, forage maturity, and climatic conditions such as rainfall and temperature. Proper evaluation of the nutritional value of pasture grasses is important but is also sometimes difficult. The quality of the improved grasses used in south and central Florida are not all the same and it is not possible to evaluate them as such. However, there is a general trend in permanent grass pastures that apparently exists on both mineral (sand) and organic (muck) soils.

At present, 90 per cent of improved pastures in Florida are composed of grasses only. Generally, permanent grass pastures in south and central Florida that have no legumes mixed in, if properly managed, will provide an excess of feed from April through August and a deficiency of feed during November through February. Pasture quality will vary in March and September, primarily due to climatic variables.

As previously mentioned the most important time, nutritionally speaking, in a cow's life is two months before and three to four months after calving, during which time her daily requirements for total digestible nutrients and digestible protein may increase 50 per cent over the maintenance amount required the rest of the year. In the majority of south and central Florida this period of the cow's life cycle occurs when the quality and quantity of permanent pasture grasses are at their lowest value nutritionally. Currently used pasture grasses generally will not furnish the nutrients that are necessary for a good beef cow to produce to her inherent ability 12 months of the year.

Legumes in combination with grasses will provide a more favorable protein and TDN level during winter and spring months than grass alone. Under average fertilization practices the grass-legume combination should result in an increase in dry matter per acre and in crude protein and phosphorus contents of forage, resulting in greater production per cow.

Considerable difference exists in Florida between perennial grasses grown on mineral and organic soils. Those grown on mineral soils have a general growth pattern ranging from a leafy plant in the spring, that is highly digestible, to a rela-

tively stemmy, relatively undigestible, mature plant in the fall months. These grasses often are unproductive during the winter months, and are low in crude protein content during this period of the year.

Properly managed pasture grasses on organic soils will have a longer growing period, will maintain a larger leaf-stem ratio, and will generally contain more crude protein than those on mineral soils. Some pasture grasses grown on soils of south Florida will grow 12 months out of the year if properly managed and will have more than 10 per cent of crude protein throughout the year (Haines *et al.*, 1965).

Maturity is probably one of the more important factors affecting the nutritive value of a pasture forage (Blaser, 1964). As the plant matures, crude fiber will increase; TDN, protein, and digestible protein will decrease.

A more detailed discussion of the quality of pasture in south and central Florida is available (Chapman *et al.*, 1964, and Haines *et al.*, 1965).

VALUE OF BLACKSTRAP MOLASSES AS A SUPPLEMENT TO PASTURE

Energy and protein constitute two of the major nutritional needs of beef cows. One of the more limiting nutritional factors on permanent pasture grasses of sub-tropic areas is inadequate digestible energy (Blaser, 1964). This appears to be particularly true where conditions provide a readily available source of nitrogen to the plant which will increase growth, crude protein, and structural carbohydrates but which will decrease soluble carbohydrate content.

Blackstrap molasses provides a readily available source of energy (Morrison, 1956, and Scott, 1953) that can be well utilized by beef cows, if properly used. Molasses should be considered as a supplement to, not a substitute for, roughage. As pointed out earlier (Table 38), there is considerable variation in the composition of blackstrap molasses. There is also much variation in permanent pasture grass. When blackstrap molasses is fed to beef cows, it is essential to know the composition of both the molasses and the available forage in order to correct imbalances or deficiencies that may occur in the protein and mineral (particularly phosphorus) content of the overall diet available to the cows. The proper evaluation of permanent grass pasture is essential.

As shown in this experiment, proper use of blackstrap molasses will improve the production of brood cows. During this experiment the crude protein level of the pasture forage almost always exceeded 10 per cent (Table 40). Studies have indicated the digestibility of the crude protein in Roselawn St. Augustine grass to be good (Haines *et al.*, 1965), and the excellent conception rates of the supplemented cows indicates that the dietary level of protein did not limit this measurement. Under these conditions mill-run cane molasses increased conception rate and weaning rate and weight and decreased death losses between birth and weaning. If the crude protein of a forage is not less than 12 per cent, on a moisture-free basis, it is unlikely that protein will limit beef cow production. In most cases, protein should not be a limiting factor if it does not fall below 10 per cent in the forage, provided cattle have access to all they will consume and that the forage does not contain too much moisture. Three to five pounds of an energy feed, such as blackstrap molasses, from approximately November 15 to March 15 will be beneficial under these pasture conditions.

The crude protein content of permanent grass pastures grown on mineral soils of Florida will fall below 10 per cent in the fall and stay low until new growth in the spring. If legumes are not utilized it will be necessary to furnish a protein supplement in addition to the blackstrap molasses. Three to five pounds of a 15 to 20 per cent crude protein-high energy supplement is suggested. This can be provided by using a urea-molasses mixture or by feeding 2 to 4 pounds of blackstrap molasses and 1 to 2 pounds of a 40 per cent supplement daily per cow. It is important to remember that both protein and energy are vital for beef cows to produce to their maximum inherent ability. It is also important to have ample available roughage when molasses is fed to beef cows. Five pounds of blackstrap molasses produced on organic soil provides an estimated 3.0 pounds of TDN (Morrison, 1956), or approximately 18 per cent of the amount suggested by NRC for nursing cows for the first 3 to 4 months after calving. This means that molasses feeding should increase the carrying capacity of pastures. This point was not determined in this trial, however, since the cows were rotated to prevent pasture differences from being confounded with molasses treatment and variation in carrying capacity of pasture due to supplemental feed was not considered in evaluation.

SUMMARY

The data from this experiment indicated that providing mill-run blackstrap molasses for 133 days during the winter was almost as beneficial nutritionally as feeding it continuously and was more profitable. Both feeding programs returned more receipts above feed cost than the program of no supplemental feed. Of particular importance in the experimental results were the very beneficial results from providing supplemental feed to the Brahman cows. The Brahmans used in this experiment had been chosen from herds throughout the state and were excellent representatives of the breed. The group of Brahmans receiving no supplemental feed did quite poorly in terms of conception rate and production per cow. The increased performance from cows receiving the molasses indicates that it is especially important that good quality Brahmans have well-balanced diets if they are going to produce to their maximum ability.

Cows receiving the molasses had a higher rate of conception and produced calves having higher weaning weights than cows receiving no supplemental molasses. Death losses of calves between birth and weaning were reduced.

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W. G. KIRK
E. M. HODGES
F. M. PEACOCK
M. KOGER

Levels of Pasture Nutrition and Breeding

Forage and beef cattle are parts of the enterprise which converts coarse feed into beef, a most nutritious food product. Pasture, to provide nutritious feed throughout the year, combined with acclimated beef cattle and orderly management are the factors which largely determine production rate. In 1956 the Range Cattle Station began a six-year study on the productivity of three herds of Shorthorn and Brahman cattle and their crosses kept on pastures designed to furnish low, medium, and high levels of nutrition. The data for four years were presented at the 1961 Beef Cattle Short Course (Cunha *et al.*, 1963). This report includes six years results.

METHOD OF PROCEDURE

The experimental herds of 60 cows each were made up as follows: ten Brahman; ten ¾ Brahman- ¼ Shorthorn; twenty ½ Shorthorn-½Brahman; ten ¾ Shorthorn-¼ Brahman; and ten Shorthorns. In the 105-day breeding season starting in March the Brahman, ¾ Brahman-¼ Shorthorn, and 10 crossbred cows in each herd were bred to a Brahman bull and the Shorthorn, ¾ Shorthorn-¼ Brahman, and 10 crossbred cows were bred to a Shorthorn bull. The two groups of 10 crossbred cows in each herd were alternated, being bred to a Shorthorn bull every second year and a Brahman bull in the intervening year. The cows in each herd were together except during the breeding season. Calves were born from January 1 to April 15 and weaned at an average age of about 215 days.

Herd 1 grazed 800 acres of native range which was divided into five fields of 160 acres each. Eighty acres of each field were burned during alternate winters. The grazing area for Herd 2 consisted of 305 acres of native range divided into two areas and 80 acres of improved pasture separated into four equal divisions. These included one each of Pensacola Bahiagrass-Hairy indigo, Pangolagrass, Pensacola Bahiagrass-white clover, and Coastal Bermudagrass. Two 20-acre fields of improved grass were subdivided to permit more efficient use of the forage. Cattle always had access to native pasture and usually to one field of improved pasture. Herd 3 was kept on 75 acres of Pangolagrass, 20 acres being overplanted with white clover and irrigated. In late winter and early spring additional pasture was provided to Herd 3 when needed.

All grass-legume pastures were fertilized with 250 pounds per acre of 0-8-24 mixture annually with grass-white clover areas being treated with additional 0-8-24 or potash. One application of complete fertilizer and at least one of nitrogen material were made annually on all improved grass pastures, making a yearly per-acre total of 100, 50, and 50 pounds of N, P_2O_5 and K_2O, respectively. Field divisions in each herd pasture allowed rotational and deferred grazing.

Results and Discussion

The production records of the three herds for six years are summarized in Table 48. It was necessary to feed Herd 1 Pangolagrass hay and cottonseed pellets during the winter to prevent excessive weight loss. The combination pasture for Herd 2 has been used since 1947. A previous study (Jones *et al.*, 1960) from 1948 to 1952 showed that 60 to 65 grade cows on this pasture without supplemental feeding had an 80 per cent weaned calf crop and the calves averaged 425 pounds when 7 months of age. Only in the 1957-58 winter, the severest on record, was it necessary to use supplemental feed. The effect was seen in the thin condition of the cows in the 1958 breeding season and 51 per cent weaned calf crop in 1959. Herd 3 was fed hay during the winter but received no protein supplement. During one summer, more than enough hay was made from one 10-acre block to supplement this herd for the approaching winter.

TABLE 48.—PRODUCTION RECORDS OF COWS FROM THREE PASTURES FOR SIX YEARS

Breeding of cows	Brah.	¾ Br- ¼ Sh	½ Sh- ½ Br	½ Sh- ½ Br.	¾ Sh- ¼ Br	Short.	
Breeding of bulls	Brah.	Brah.	Brah.	Short.	Short.	Short.	
Breeding of calves	Brah.	⅞ Br- ⅛ Sh	¾ Br- ¼ Sh	¾ Sh- ¼ Br	⅞ Sh- ⅛ Br	Short.	Pasture Summary
Native Pasture:							
Per cent calf crop	54	66	52	61	72	62	61
Av. weaning weight	355	380	418	395	371	256	360
Av. 205-day weight	323	360	386	350	341	238	335
Av. calf weight per cow	192	249	217	243	269	158	219
Combination Native and Improved Pasture:							
Per cent weaned calf crop	64	77	82	84	63	65	73
Av. weaning weight	399	440	495	469	400	363	430
Av. 205-day weight	370	405	461	435	377	335	398
Av. calf weight per cow	254	340	406	392	254	236	313
Intensive grass program plus irrigated clover:							
Per cent weaned calf crop	81	68	83	84	74	65	76
Av. weaning weight	390	456	511	495	449	404	448
Av. 205-day weight	389	426	475	449	417	370	420
Av. calf weight per cow	317	309	423	417	331	263	340
Summary of 3 pasture treatments:							
Cow breeding seasons	178	174	171	175	156	183	1037
Per cent weaned calf crop	66	70	73	74	70	64	70
Av. weaning weight	383	427	485	459	410	343	417
Av. 205-day weight	364	398	450	418	381	316	370
Av. calf weight per cow	254	299	354	351	286	219	292
Av. slaughter grade*	8	9	10	10	9	9	9

*Slaughter grades: 6—Low Standard; 7—Standard; 8—High Standard; 9—Low Good; 10—Good; 11—High Good.

WEANED CALF CROP

Herd 1 had a 61 per cent weaned calf crop in the six-year period with the ¾ Shorthorn-¼ Brahman cows bred to a Shorthorn bull, 11 per cent above, and the ½ Shorthorn-½Brahman cows mated to Brahman bulls, 9 per cent below the average.

Herd 2 grazing a combination native and improved pasture had a 73 per cent weaned calf crop with the crossbred cows bred to Shorthorn bulls 11 per cent above average; those bred to a Brahman bull, 9 per cent above average, and the ¾ Shorthorn-¼ Brahman and Shorthorn cows, 10 and 8 per cent respectively below the average.

Herd 3 on improved pasture had a 76 per cent weaned calf crop. The crossbred cows bred to Shorthorn and Brahman bulls had 84 and 83 per cent calf crop, respectively, with Shorthorn cows 11 per cent below the average. The high quality of the Herd 3 pasture was indicated by the high condition of the cows and calves. This may have reduced conception rate and caused greater calf loss from birth to weaning than with Herds 1 and 2. These are reasons for the small difference of 3 per cent in weaned calf crop between Herds 2 and 3.

The three herds averaged 70 per cent weaned calves, ranging from a high of 75 per cent from crossbred cows bred to a Shorthorn bull down to 64 per cent for Shorthorn cows so bred.

ADJUSTED CALF WEIGHT AT 205 DAYS

The average calf weaning weights for the six years were 360, 430, and 448 pounds for Herds 1, 2, and 3, respectively, with an average for calves from the three herds of 417 pounds. These weights adjusted to 205 days of age were 335, 398, and 420 pounds for Herds 1, 2, and 3 and 370 pounds for the 725 weaned calves from the three herds.

The ¾ Brahman-¼ Shorthorn calves from the three herds had an average of 450 pounds at 205 days of age, followed in descending order by ¾ Shorthorn-¼ Brahman, ⅞ Brahman-⅛ Shorthorn, ⅞ Shorthorn-⅛ Brahman, Brahman and Shorthorn.

TABLE 48.—*Production Records of Cows from Three Pastures for Six Years*

Breeding of cows	Brah.	¾ Br-¼ Sh	½ Sh-½ Br	½ Sh-½ Br.	¾ Sh-¼ Br	Short.	
Breeding of bulls	Brah.	Brah.	Brah.	Short.	Short.	Short.	
Breeding of calves	Brah.	⅞ Br-⅛ Sh	¾ Br-¼ Sh	¾ Sh-¼ Br	⅞ Sh-⅛ Br	Short.	Pasture Summary
Native Pasture:							
Per cent calf crop	54	66	52	61	72	62	61
Av. weaning weight	355	380	418	395	371	256	360
Av. 205-day weight	323	360	386	350	341	238	335
Av. calf weight per cow	192	219	217	243	269	158	219
Combination Native and Improved Pasture:							
Per cent weaned calf crop	64	77	82	84	63	65	73
Av. weaning weight	399	440	495	469	400	363	430
Av. 205-day weight	370	405	461	435	377	335	398
Av. calf weight per cow	254	340	406	392	254	236	313
Intensive grass program plus irrigated clover:							
Per cent weaned calf crop	81	68	83	84	74	65	76
Av. weaning weight	390	456	511	495	449	404	448
Av. 205-day weight	389	426	475	449	417	370	420
Av. calf weight per cow	317	309	423	417	331	263	340
Summary of 3 pasture treatments:							
Cow breeding seasons	178	174	171	175	156	183	1037
Per cent weaned calf crop	66	70	73	74	70	64	70
Av. weaning weight	383	427	485	459	410	343	417
Av. 205-day weight	364	398	450	418	381	316	370
Av. calf weight per cow	254	299	354	351	286	219	292
Av. slaughter grade*	8	9	10	10	9	9	9

*Slaughter grades: 6—Low Standard; 7—Standard; 8—High Standard; 9—Low Good; 10—Good; 11—High Good.

WEANED CALF CROP

Herd 1 had a 61 per cent weaned calf crop in the six-year period with the ¾ Shorthorn-¼ Brahman cows bred to a Shorthorn bull, 11 per cent above, and the ½ Shorthorn-½Brahman cows mated to Brahman bulls, 9 per cent below the average.

Herd 2 grazing a combination native and improved pasture had a 73 per cent weaned calf crop with the crossbred cows bred to Shorthorn bulls 11 per cent above average; those bred to a Brahman bull, 9 per cent above average, and the ¾ Shorthorn-¼ Brahman and Shorthorn cows, 10 and 8 per cent respectively below the average.

Herd 3 on improved pasture had a 76 per cent weaned calf crop. The crossbred cows bred to Shorthorn and Brahman bulls had 84 and 83 per cent calf crop, respectively, with Shorthorn cows 11 per cent below the average. The high quality of the Herd 3 pasture was indicated by the high condition of the cows and calves. This may have reduced conception rate and caused greater calf loss from birth to weaning than with Herds 1 and 2. These are reasons for the small difference of 3 per cent in weaned calf crop between Herds 2 and 3.

The three herds averaged 70 per cent weaned calves, ranging from a high of 75 per cent from crossbred cows bred to a Shorthorn bull down to 64 per cent for Shorthorn cows so bred.

Herd 2 over Herd 1 varied from 120 to 119 per cent; for Herd 3 over Herd 1 from 125 to 124 per cent. The significant figures are the 43 per cent superiority in average yearly production per cow for Herd 2 and the 55 per cent superiority for Herd 3 over Herd 1. This measurement combines both per cent calf crop and total weaning weight of calves, giving the most accurate estimate of the total effect of the quality of pasture on herd productivity. There was an improvement in slaughter grade of 13 and 25 per cent for Herds 2 and 3, respectively, over Herd 1.

TABLE 49.—PRODUCTION OF THREE HERDS ON A PERCENTAGE BASIS

KIND OF PASTURE	NATIVE	COMBINATION NATIVE AND IMPROVED	IMPROVED PLUS IRRIGATED CLOVER
Production factors:			
Per cent calf crop	100	120	125
Weaning weight	100	119	124
205-day weight	100	120	125
Yearly calf weight per cow	100	143	155
Slaughter grade of calf	100	113	125

The total weaned weight of the 204 calves from Herd 1 during six years was 73,620 pounds, which average 219 pounds yearly per cow and 15 pounds per acre of native pasture. Kirk *et al.*, 1954, reported from an earlier study that twelve grade cows on 160 acres of this same pasture without supplemental feeding from 1950 to 1953 had an average calf production of 247 pounds per cow or 19 pounds per acre of range. These data showed that grade cows on native pasture without supplemental feeding had a greater calf production per cow and per acre of range than did cows with more improved breeding.

SUMMARY

This study, utilizing Shorthorns, Brahmans, and their crosses for a six-year period (1955 to 1960) summarizes reproduction records of 1037 cow-breeding seasons. The data reported include weaning per cent, weaning weight, and adjusted 205-day weight and slaughter grade for 725 calves, and yearly production per cow.

Herd 1 on native pasture had a 61 per cent weaned calf crop and produced 219 pounds calf weight yearly per cow, followed by Herd 2 on a combination improved and unimproved pasture with 73 per cent and 313 pounds, and Herd 3, kept entirely on improved pasture, being highest with 76 per cent and 340 pounds, respectively. The weaned calf crop for the three herds was 70 per cent with an average yearly production of 292 pounds per cow.

The ½ Shorthorn-½ Brahman crossbred cows weaned 74 per cent calves when bred to a Shorthorn bull and 73 per cent when mated to Brahman bulls. These cows produced the heaviest calves averaging 459 and 485 pounds, respectively, for the two groups, with a slaughter grade of Good for both. The calves from the ¾ Brahman- ¼ Shorthorn cows weighed 427 pounds and those from the ¾ Shorthorn- ¼ Brahman cows averaged 410 pounds, followed by 383 pounds from Brahman and 343 pounds from Shorthorn cows.

Crossbred cows bred to Brahman bulls had an average annual weaned calf production of 354 pounds and cows of the same breeding produced 351 pounds when bred to Shorthorn bulls, the highest for the five breed groups.

Production rate increased as the nutrition level improved with the Shorthorn Brahman crossbred cows producing at the highest level on all programs.

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M. KOGER
A. C. WARNICK

Various Pasture Programs

The pregnancy rate varied from a low of 48 per cent to a high of 89 per cent in a study conducted on 13 commercial ranches (Warnick *et al.*, 1960). One of the primary reasons for this large variation in reproduction rate was due to differences in forage production on the different ranches. Differences in type and management of pasture influence forage production which in turn determines overall level of nutrition for the breeding herd. The objective of this chapter is to compare calf production of cows on two types of pasture in the crossbred herd at the Beef Research Unit near Gainesville, Florida.

Two types of improved pasture were established; the all grass pastures consisting of Pangola grass and Pensacola Bahia were planted in separate pastures. After two years Coastal Bermuda grass was planted and replaced a part of the Pangola grass. The other type was clover-grass pastures consisting of the same grasses overplanted with a clover mixture of Nolin's Louisiana White, Ladino Red and Hubam in October. In the subsequent years Louisiana White was the only clover that persisted, so the clover-grass pastures were essentially the grasses plus white clover.

The pastures were stocked with Commercial Brahman x Native two-year-old heifers typical of the majority of the cows on commercial ranches in 1952. During the five-year period the cows were bred to Angus, Brahman, Hereford and Shorthorn bulls during a three-month breeding season from March 1 to June 1. The bulls were bred in single sire herds and rotated at 12 day intervals to minimize differences in bull fertility.

The type of pasture that heifers grazed from weaning until two years of age when they entered the breeding herd influenced their reproductive performance in the subsequent years (Table 51). Heifers raised on the clover-grass pastures had a 96 per cent calving rate compared to 81 per cent for those raised on grass pastures. The weaning percentage was 89 and 76 per cent for the above two groups, respectively. Weaning weights of calves were not greatly different (434 vs. 429) from heifers raised on the two pastures but the production per cow

TABLE 51.—PRODUCTION PERFORMANCE OF FEMALES GROWN AS HEIFERS ON DIFFERENT TYPES OF PASTURE

ITEM	PASTURE ON WHICH REARED	
	GRASS	CLOVER-GRASS
Number of cows	112	183
Calving per cent	81	96
Survival per cent	94	93
Weaning per cent	76	89
Weaning weight, lbs.	429	434
Production per cow, lbs.	326	386
Avg. wt. of cows, lbs.	893	940

was 16 per cent greater for those heifers raised on the clover-grass pastures. This difference results from the increased weaning percentage.

During the second phase (1960-64) of the breeding program at the Beef Research Unit cows were wintered with silage on a moderate winter feeding program so differences due to pasture were somewhat reduced. The cows grazing clover-grass pastures had a 96 per cent calving rate vs. 91 per cent for cows on grass pasture (Table 52). The respective weaning percentages were 93 and 89 for cows on the two pastures. There was a 21 pound advantage in calf weaning weight for cows on the clover-grass pastures. The production per cow was 472 on clover-grass compared to 433 for cows on grass, an advantage of 8 per cent for cows on the clover-grass pastures.

SUMMARY

Young Brahman x Native commercial cows grazing clover-grass improved pastures had a 19 per cent higher calving rate and a 15 per cent higher weaning rate than similar cows grazing

all grass pastures when bred to the same bulls. This difference was due to a failure of ovarian activity and estrus and a longer interval from calving to first estrus in cows on the grass pastures. Although weaning weight of calves from cows on the two types of pasture were similar, cows on clover-grass pastures produced 20 per cent more pounds of weaned calf per cow than those on grass pastures.

Heifers grazed from weaning to two years of age on clover-grass pastures had a 13 per cent higher weaning rate than heifers raised on grass pastures. This would indicate a favorable influence of the clover pastures on the developmental physiology of the reproductive system during the first two years which carries over into reproductive performance of cows while in the breeding herd. As a result of the increased reproductive rate, heifers raised on the clover-grass pastures weaned 16 per cent more pounds of calf per cow than those raised on grass pastures.

TABLE 52.—PRODUCTION PERFORMANCE OF COWS GRAZING DIFFERENT TYPES OF PASTURE WITH MODERATE SUPPLEMENTAL WINTER FEEDING (1960-1964)

Item	Type of pasture: Grass	Clover-grass
Number of cows	160	200
Calving per cent	91	96
Survival per cent	98	97
Weaning per cent	89	93
Weaning wt., lbs.	487	508
Production per cow, lbs.	433	472
Avg. wt. of cows, lbs.	1028	1021

A comparison of cows wintered on a moderate feeding program and grazed on two types of pasture was made from 1960 to 1964. The weaning percentage and weaning weight was 93 per cent and 508 pounds in cows on clover-grass pastures versus 89 per cent and 487 pounds for cows on all grass pastures. The production per cow at weaning showed an 8 per cent advantage for cows on the clover-grass pastures.

Wherever soil and moisture conditions are favorable for clover production, clover should be seeded to improve reproductive performance of the cow herd and overall production per cow.

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J. F. HENTGES, JR.

Level of Feeding and Bull Performance

The demand by commercial cattlemen for performance test data before purchase of beef bulls plus the expanding adoption of the practice of artificial insemination has increased the need for information on the relationship of level of feeding to reproductive performance of bulls. While very little research has been done on the effect of overnutrition (excessive fattening), a number of researchers have studied the effects of undernutrition (starvation) on reproductive perfomance. To set the stage for a discussion of the research findings on this subject, it seems expedient firstly to outline current bull feeding practices on ranches and secondly, to relate the pertinent research findings to farm or ranch practices.

CURRENT PRACTICES

PRIOR TO WEANING

Three methods of feeding suckling beef calves are generally practiced:

1. Own dam, on pasture, access to mineral mixture.
2. Own dam, on pasture, access to concentrates in a creep feeder.
3. Nurse cow or own dam suckled twice daily, hand-fed concentrates and forage in a barn.

At this age, it is generally believed that feeding methods or levels are of minor importance for subsequent reproductive performance. While economics dictate the least-cost method of raising suckling bull calves and some animal breeding special-

ists advise against creep feeding or hand feeding of suckling beef calves, there is a general trend toward the offering of supplemental concentrates in a creep feeder starting 30 to 90 days before weaning.

WEANING TO 12-15 MONTHS OF AGE

All weaned bull calves in breeding herds of registered cattle should be "performance tested" for at least 140 days following weaning. Methods of feeding during performance tests vary widely:

1. Full feed of forage (pasture), access to mineral mixture.
2. Full feed of forage (pasture) with limited supplemental concentrates.
3. Full feed of fresh chopped forage in confinement (limited exercise area) with or without supplemental concentrates.
4. Full feed of concentrates on pasture.
5. Full feed of concentrates in drylot (limited exercise area).

Some breeders believe that the method of feeding at this age will have no effect on subsequent reproductive performance because seven to fifteen months will elapse between the end of the performance test and the beginning of breeding service. Others believe that damage may be done to the feet, legs and reproductive system by improper methods and levels of feeding during a performance test and that subsequent reproductive performance may be permanently limited. There is a trend among progressive breeders toward the full feeding of supplemented forage for economical gains of about 1.8 to 2.2 pounds per day (variable with breed).

END OF PERFORMANCE TEST (12-15 MONTHS OF AGE) TO USUAL BREEDING AGE (22-27 MONTHS)

Because bulls are sold at different ages in different regions, the level and method of feeding varies widely after a performance test. Each of the five methods of feeding during performance tests are used during the fitting of bulls for sales.

Without question, breeders believe that the level and method of feeding at this age will affect subsequent reproductive performance, especially in cases where bulls are changed immediately from an ideal environment to a rugged range existence. There is a trend among progressive breeders toward the feeding of groups of bulls on high quality pastures, properly supple-

mented with minimal amounts of concentrates, for gains of about 1.5 pounds per day (variable with breed) and the production of physically sound, not fat, sale bulls which are adapted to pasture environmental conditions.

During breeding season

Because most beef bulls serve in large multiple-sire herds, the levels of supplemental feed offered to bulls in service vary from almost none under pasture mating to liberal amounts under hand-mating conditions. The methods of providing feed for bulls in breeding herds are as follows:

1. Forage (pasture with or without hay and silage), access to mineral mixture.
2. Forage (pasture with or without hay and silage) with a limited concentrate supplement (pellets fed at 1 to 3 day intervals, salt or fat-concentrate mixtures, molasses-urea solutions, blocks of compressed concentrates, etc.).
3. Green chopped or stored forage fed with supplemental concentrates to bulls in confinement.

In some commercial herds where supplemental feeding of concentrates is not practiced, the nutritional condition of bulls is regulated by rotating bulls from service in the breeding herd to small pastures where they are fed concentrates and forage.

Between breeding seasons

While the level of feeding between breeding seasons may be dependent on the individual bull, the method of feeding generally is determined by the kind of enterprise—registered or commercial herd.

1. In registered herds and small commercial herds, individual bulls are usually kept in small enclosures (inferior pastures) and are fed supplemental concentrates in accordance with the degree of fatness desired. The belief that fat bulls are attractive to purchasers frequently causes registered herd-sires to be unnecessarily overweight.
2. In commercial herds, large numbers of bulls are sorted by ages into large pastures with access to mineral mixtures and may not be offered supplemental concentrates until 60-90 days before the breeding season.

Trends are not evident toward change from the current practices which frequently result in some bulls becoming excessively fat in registered herds and some bulls becoming decidedly too thin in commercial herds.

Because the practical farm and ranch problems of bull infertility associated with faulty nutrition or management seem to fall into two categories, overfeeding or underfeeding, the research with bulls which has been reported will be discussed under these two headings.

OVERNUTRITION

There are few reports based on experimentation with bulls to support the widespread belief among cattlemen that infertility may result from overnutrition.

Hammond (1952) questioned whether one reason for low sex drive (libido) and marginal reproductive performance of fat males might be the accumulation of fat deposits in the scrotum. Olson (1952) observed a decreased ability of an overweight dairy bull to serve cows. Ball *et al.* (1964) found a higher incidence of seminal vesiculitis characterized by enlarged seminal vesicles and pus in the semen of young sale bulls confined together and fed a gain-producing ration. Flipse and Almquist (1961) concluded from an experiment with Holstein bulls fed from birth to four years of age on different levels of energy intake that "from a practical standpoint, the development of weaknesses of the feet and legs and the lower level of sexual activity in the group (fed 130 per cent of recommended energy intake) suggest that these factors would soon limit the useful life of these bulls." Research with young dairy bulls has shown that a high plane of nutrition brings the attainment of puberty at an earlier age (Flipse *et al.*, 1953, Flipse and Almquist, 1961 and 1963, Bratton *et al.*, 1957, 1959, and 1961).

It is questionable whether inferences drawn from reproductive physiology research with fat heifers and cows have any applied value with the opposite sex. Excellent papers and reviews of the literature on this subject have been reported by Asdell (1949), Hammond (1952), Meites (1953), Casida (1959), Reid (1960), and Totusek *et al.* (1961). In general, fatness in the female has been associated with lowered reproductive performance.

An extensive study of two methods of feeding beef bulls which resulted in two planes of nutrition, was reported at the

mented with minimal amounts of concentrates, for gains of about 1.5 pounds per day (variable with breed) and the production of physically sound, not fat, sale bulls which are adapted to pasture environmental conditions.

During breeding season

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An extensive study of two methods of feeding beef bulls which resulted in two planes of nutrition, was reported at the

University of Florida (Hentges *et al.*, 1964, and Hentges, 1964). Their objective was to measure the comparative effects of feeding a high-concentrate and a high-forage diet on the feedlot performance and potential reproductive potency of beef bulls during a performance test and subsequent months prior to their sale as commercial bulls at 22 to 25 months of age.

EXPERIMENTAL BULLS

Fall weaned Angus, Hereford and Brahman bulls which averaged 570 pounds in weight and 325 days in age were assigned to two feed treatment groups according to breed, age and weight. Group I was fed forage ad lib while Group II was fed concentrates ad lib.

The experiment was divided into two phases with each phase characterized by a change in composition of the diet offered to the forage-fed bulls. Phase I was a 196-day performance test which ended in June. In this phase, one group of 14 bulls were hand-fed 7 pounds of a concentrate mixture per head once a day plus all of the corn silage that they would voluntarily consume. A similar group of 14 bulls was offered the same concentrate mixture ad lib from a self-feeder. Table 53 shows the proximate composition of the diets during Phases I and II. Each group was kept in a fertilized grass pasture which provided 0.5 acre of grazing per head.

Phase II was a 140-day extension of the same treatments with 20 of the same bulls. In Phase II, the forage was changed from corn silage to fertilized grass pasture and the amount of concentrates offered to the group fed forage ad lib was increased from 7 to 8 pounds per head. The bulls fed concentrates ad lib were given free access to the same concentrate feed mixture from a self-feeder. The bulls offered forage ad lib were provided with 1.0 acre of Coastal Bermuda grass pasture per head while the bulls fed the concentrate ad lib were provided with 0.5 acre per head.

FEED INTAKE

During Phase I, the average daily feed intake per bull by the group fed concentrates ad lib was 15.3 pounds of the concentrate mixture. Bulls offered corn silage ad lib consumed 22.8 pounds of corn silage plus 7 pounds of concentrate mixture. Although the average daily gains were smaller during Phase

II, bulls in the concentrate and forage-fed groups consumed an average of 22.8 and 8.0 pounds, respectively, of the concentrate mixture per head per day.

WEIGHT GAINS

The initial and final average weights were 590 and 1,230 pounds in the group fed forage ad lib and 550 and 1,305 pounds in the group fed concentrate ad lib. Higher gains were recorded during Phase I than during Phase II. As illustrated in Table 54, bulls fed concentrates ad lib had very high average daily

TABLE 53.—APPROXIMATE COMPOSITION OF CONCENTRATE MIXTURE FED DURING PHASE I AND PHASE II*

INGREDIENT	POUNDS, AIR-DRY
Corn meal, yellow	54.0
Citrus meal, dried	15.8
Soybean oil meal, 44%	3.5
Cottonseed meal, 41%	3.5
Urea, 262%	1.0
Molasses, cane, standard	5.0
Alfalfa meal, dehydrated, 17%	5.0
Mineral and vitamin mixture†	2.0
Corn cobs, coarsely ground	10.0
Aurofac 10	*0.0375*
Defluorinated phosphate	0.2
TOTAL	100.0375

*Crude protein content averaged 13.3%.
†*Mineral mix contained* 18.9% calcium, 5.5% phosphorus, 30% sodium chloride, 1.4% iron, 0.108% copper, 0.01% cobalt, 0.48% manganese and 0.01% iodine. Vitamin mix contained 10,000 U.S.P. units of vitamin D_2 per lb. and was adjusted to provide an average intake of 20,000 I.U. vitamin A per day.

TABLE 54.—SUMMARY OF WEIGHT DATA AND AVERAGE DAILY GAIN FOR PHASE I AND PHASE II

	FORAGE AD LIB	CONCENTRATE AD LIB
Avg. initial weight, lbs.	590	550
Trial length, days		
Phase I	196	196
Phase II	140	140
Avg. daily gain, lb.		
Phase I	[illegible]	2.44
Phase II	1.45	[illegible]
Avg. final weight, lb.	1230	[illegible]

gains of 2.48 and 1.95 pounds during Phase I and Phase II, respectively. The bulls receiving forage ad lib made lower but very satisfactory average daily gains of 2.05 and 1.46 pounds for Phase I and Phase II, respectively. Statistical analyses of weight gain data on all bulls revealed a significant ($P < .01$) difference between phases and a dietary treatment effect ($P < .01$) in Phase II. Figure 10 illustrates their relative appearance and fatness.

TABLE 55.—SUMMARY OF DATA ON FEED COSTS DURING PHASE I AND PHASE II

	Phase I		Phase II	
	Forage ad lib	Concentrate ad lib	Forage ad lib	Concentrate ad lib
Concentrate costs, dollars				
Total cost	654.30	1,424.97	380.12	1,087.32
Cost/head/phase	46.70	101.78	38.01	108.73
Cost/head/day	.24	.52	.27	.78
Silage costs, dollars				
Total cost	269.49	———	77.92	———
Cost/head/phase	19.25	———	7.79	———
Cost/head/day	.10	———	.06	———
Pasture costs, dollars				
Total costs	69.62	69.62	42.84	21.42
Cost/head/phase	4.97	4.97	4.28	2.14
Total cost	993.41	1,494.59	500.88	1,108.74
Total cost/head	70.96	106.76	50.10	110.87
Difference in cost per bull		35.80		60.77

FEED COST FOR EACH METHOD OF FEEDING

A comparison of total feed costs during the two phases of the experiment is shown in Table 55. The difference in feed cost per bull between the two groups was $35.80 and $60.77 more for the group fed concentrates during Phase I and Phase II, respectively. The difference between lots in cost per bull per day was 26 cents more during Phase II than Phase I due to the larger daily consumption of concentrates by the concentrate-fed bulls during Phase II.

SEMEN EVALUATION

Semen was collected by electroejaculation with a Nicholson all-transistor ejaculator. The procedure involved insertion of a 2½ inch probe into the rectum, massage of the testicles, elec-

trical stimulation rhythmically with voltage being increased stepwise until ejaculation was complete. If visual observation of the sample revealed pus cells, low concentration of sperm cells or contamination, a second ejaculate was obtained. Semen was colleted and evaluated on day 1, 28, 112, and 196 of Phase I and on

FIGURE 10. Note the difference in degree of fatness between bulls full-fed concentrates (upper) and bulls full-fed forage (lower). The forage-fed bulls were fat enough to be attractive to bull buyers and their reproductive performance was satisfactory. The concentrate-fed bulls were more attractive to some buyers but 90 per cent exhibited impaired reproductive performance.

TABLE 56.—SUMMARY OF DATA ON SEMEN CHARACTERISTICS AT VARIOUS SEMEN COLLECTIONS DURING PHASE I

Criteria	Days on Experiment: 1		28		112		196	
	Forage ad lib.	Concentrate ad lib.	Forage ad lib.	Concentrate ad lib.	Forage ad lib.	Concentrate ad lib.	Forage ad lib.	Concentrate ad lib.
Average age, days	321	329	349	356	433	440	517	524
Average body weight (lb.)	590	550	628	611	798	808	998	1043
Vigor score*	3.7	3.4	2.6	2.4	2.5	2.2	3.0	2.4
Sperm motility (%)	34.6	29.3	30.0	44.3	50.0	61.4	51.4	57.1
Concentration score†	3.0	3.3	3.5	3.1	3.0	2.5	2.6	2.7
Sperm count/mm³ (x 10⁶)	307.7	239.3	225.0	300.0	317.9	353.6	375.0	367.9
Abnormal cells (%)	47.7	42.1	24.6	28.9	30.7	23.8	28.5	27.1
Live cells (%)	43.9	40.0	58.6	54.3	59.3	58.6	53.2	72.9
Adhesion score‡	4.4	4.9	4.1	4.3	2.1	1.6	1.2	1.1
Volume (ml)	6.5	7.6	8.6	6.7	8.0	6.9	5.7	3.3

*Very good, 1; good, 2; fair, 3; poor, 4 and none, 5.

†Very concentrated, 1; concentrated, 2; milky but dilute, 3 and watery, 4.

‡Based on per cent penis-sheath adherence: None, 1; 15%, 2; 30%, 3; 45%, 4; 60%, 5 and penis not extended for examination, 6.

TABLE 57.—SUMMARY OF DATA ON SEMEN CHARACTERISTICS AT VARIOUS SEMEN COLLECTIONS DURING PHASE II

CRITERIA	DAYS ON EXPERIMENT					
	196		280		336	
	FORAGE AD LIB	CONCENTRATE AD LIB	FORAGE AD LIB	CONCENTRATE AD LIB	FORAGE AD LIB	CONCENTRATE AD LIB
Average age, days	517	524	603	612	662	670
Average body weight (lb.)	998	1043	1125	1143	1230	1305
Vigor score*	3.0	2.4	2.0	2.3	1.9	1.9
Sperm motility (%)	*31.4*	*57.1*	53.0	60.0	70.0	66.0
Concentration score†	2.6	2.7	2.5	2.3	1.9	2.4
Sperm count/mm³ (x 10^6)	375.0	367.9	410.0	455.0	595.0	445.0
Abnormal cells (%)	28.5	27.1	30.0	30.0	30.5	36.0
Live cells (%)	53.2	72.9	63.5	65.0	65.0	58.0
Adhesion score‡	1.2	1.1	—	—	—	—
Volume (ml)	5.7	3.3	3.4	5.0	5.1	3.0

*Very good, 1; good, 2; fair, 3; poor, 4 and none, 5.

†Very concentrated, 1; concentrated, 2; milky but dilute, 3 and watery, 4.

‡Based on per cent penis-sheath adherence: None, 1; 15%, 2; 30%, 3; 45%, 4; 60%, 5 and penis not extended for examination, 6.

produced by the two groups was varied, ranging from 3.0 to 8.6 ml. per ejaculate. This variation was noted among bulls within both groups and among different collections. There was significantly more (P. $<.01$) semen collected from both groups in Phase I, the average semen volumes being 7.2 and 6.1 ml. per ejaculate for forage- and concentrate-fed bulls respectively. In Phase II, average semen volumes were 4.7 and 3.8 ml. per ejaculate in the respective dietary groups. The variation was due to a change from a whole collection technique during Phase I to collection of partial ejaculates during Phase II to give a more concentrated semen sample. No statistically significant differences in semen volume were found between treatments during Phase I or Phase II. These results are in agreement with those reported by Flipse *et al.* (1952), who found no significant differences in volume of semen produced by bulls fed all-roughage and all-concentrate rations and Flipse and Almquist (1961) who reported that sperm output and extra-gonadal sperm reserves were similar among bulls fed recommended and high levels of energy intake. Olson (1952), in a similar study with dairy bulls, reported average semen volumes of 2.7 and 3.0 ml. per ejaculate for a low (70 per cent TDN) and high (130 per cent TDN) level of energy intake, respectively.

Vigor, motility, and sperm concentration

The feeding of concentrates ad lib resulted in a higher motility of sperm and greater sperm concentration throughout Phase I and during part of Phase II. Average vigor scores at the beginning and end of Phase I were 3.7 and 3.0 respectively for the forage-fed group and 3.4 and 2.4 respectively for the concentrate-fed group. Motility scores recorded for the group fed concentrates during Phase I were consistently higher than values obtained for the forage-fed group. Average sperm concentration scores and estimated average number of sperm cells produced by bulls receiving concentrates ad lib were also higher thoughout Phase I and during part of Phase II. These findings are in accordance with results of dairy bull research reviewed by Casida (1959) and Flipse and Almquist (1961). They reported attainment of puberty (sperm production and libido) at an earlier age and higher semen quality in bulls fed a high energy intake. The quantity of feed offered to bulls in the Florida study was higher than in previous experiments and the study

was continued longer after puberty. The feeding of concentrates ad lib resulted in slightly higher semen quality during Phase I but by the end of Phase II, the results had reversed with the best quality semen being obtained from bulls that received forage ad lib. These differences were not statistically significant.

Henderson and Norton (1960) and Quicke and Phillips (1950) showed that moderate amounts of grass silage may be fed without impairing fertility of bulls. Flipse *et al.* (1952) studied the effects of feeding large amounts of grass silage versus large amounts of concentrates to dairy bulls and reported no statistically significant differences in semen quality between the two groups. The findings in this experiment are in agreement since significant differences were not found among any of the criteria used to evaluate semen quality from bulls fed concentrates ad lib versus forage ad lib.

LIVE AND ABNORMAL CELLS

The percentage of live cells at the beginning and end of Phase I were 43.9 and 53.2 respectively in the group fed forage and 40.0 and 72.9 respectively in the concentrate-fed group. Per cent of live cells was higher for bulls fed concentrate ad lib during part of Phase II. At the last semen evaluation when the animals were approximately 22 months old, the percentage of live cells was 65.0 and 58.0 for forage- and concentrate-fed bulls respectively. Similar values were reported by Flipse *et al.* (1952) and Flipse and Almquist (1961) for 20-month-old dairy bulls. Hafez (1962) reported the percentage of normal sperm to be 60 to 80 per cent for males with higher fertility.

The percentages of abnormal cells recorded at the first semen collection were 47.7 and 42.1 in the forage- and concentrate-fed groups respectively. These high values were probably due to faulty technique since a lower incidence of abnormal cells was observed at subsequent semen collections. Bichan and Hunter (1961) reported that 50 per cent of the sperm were dead in the first ejaculate obtained from beef calves. When the number of abnormalities reaches 50 per cent of the total number of sperm cells in the ejaculate, the mature male has impaired fertility and, as a rule, is sterile (Nalbandov, 1958). An excellent review of genetic causes of faulty germ cells and low fertility was reported by Johansson (1960).

The incidence of pus cells was highest in bulls fed concen-

trates ad lib. Carroll *et al.* (1963) summarized breeding soundness data from examinations of 10,940 bulls and reported that inflammation of the seminal vesicles was observed in 338 of 7,350 bulls. This condition was most common in young beef bulls confined together and fed a gain-producing ration. Their criteria was seminal vesiculitis were enlarged glands, pain on palpation, and pus in the semen. The latter condition is described in detail by Ball *et al.* (1964), who related the riding activity of bulls to the incidence of pus cells. In the Florida study, the highest incidence of pus cells was observed in the less active concentrate-fed bulls.

LIBIDO AND MATING BEHAVIOR

Libido (sex drive) is the potential intensity of sexual behavior, measured in the male as relative values based on the frequency and spacing of mounts, intramissions, and successful copulations (Hafez, 1962). These were evaluated twice during Phase II, on a hot summer day in August and a cool fall day in October. This was done by exposing each bull individually to an estrogenized heifer which was in simulated standing heat (estrus) and secured in a breeding chute. The heifers were estrogenized by an intravenous injection of 4 ml. of diethylstilbestrol. This was administered on the day prior to the mating behavior test. Each bull was allowed a maximum of 10 minutes with the heifer. Records were kept on the degree of interest displayed by the bulls, the number of mounts made, the time interval to first mount, and the number of matings completed.

When libido was evaluated in August, the time interval to first mount and time interval to first mating were 0.35 and 0.91 minutes respectively for the forage-fed group and 3.3 and 4.0 minutes respectively for the group fed concentrates. The average libido score was 5.2 for the bulls fed forage and 4.1 for the concentrate-fed bulls (See Table 58). The libido scores indicate that 100 per cent (ten bulls) in the group fed forage accomplished mating compared to only 10 per cent (one out of ten bulls), in the group fed concentrates. The average temperature and relative humidity recorded during the first libido evaluation was 87.7°F. and 59.7 per cent respectively and 68.7°F. and 80 per cent respectively during the second evaluation. At the time libido was first evaluated, the prevailing high temperature possibly had an inhibitory effect on the sexual drive, being more noticeable in the group fed

concentrates. At the second evaluation of libido in cooler weather, criteria such as interval to first mount and interval to first mating were improved in both groups. In general, the lack of libido displayed by bulls in the group fed concentrates seemed to be associated with their physical condition. The excessive fatness of these bulls apparently had an inhibitory effect on their sexual drive, becoming more apparent during high environmental temperatures. With dairy bulls, *Flipse and Almquist (1961)* reported a difference in reaction time to ejaculation of about 8 minutes between 3-year-old bulls fed a high energy intake (9.2 minutes) and bulls fed a recommended energy intake (less than 1.5 minutes).

TABLE 58.—SUMMARY OF LIBIDO DATA FOR THE TWO TREATMENT GROUPS OF BULLS ON 81ST AND 140TH DAYS OF PHASE II

Criteria and Treatment Groups	Day of Phase II	
	81	140
Interval to first mount, min.		
Forage ad lib	1.3	.21
Concentrate ad lib	3.3	.74
Total number of mounts		
Forage ad lib	1.8	1.7
Concentrate ad lib	3.6	5.5
Interval to first mate, min.		
Forage ad lib	1.8	1.6
Concentrate ad lib	9.4	9.1
Libido score*		
Forage ad lib	5.2	5.5
Concentrate ad lib	4.1	4.1
Total number of matings		
Forage ad lib	9†	9†
Concentrate ad lib	1	1

*No interest, 1; Smelled and extended penis, 2; mounted and erected penis, 3; mounted without mating in 5 attempts or 10 minutes, 4; mounted and mated on 2nd to 5th attempt, 5; and mounted and mated on 1st attempt, 6.
†One bull which failed to mate during this period successfully mated at other periods; therefore, 100% of forage *ad libitum* bulls mated but only one of the other group (10%) mated during each period.

GRAZING AND NON-GRAZING ACTIVITY

During Phase II, the bulls were checked for grazing and non-grazing activity as an indication of the relative amount of each kind of exercise taken by each group. They were checked for activity at 15-minute intervals during the daylight hours on three

consecutive days in September. The percentages of time spent grazing were 25.4 and 12.0 for forage- and concentrate-fed groups respectively (See Table 59). The percentages of time recorded as non-grazing activity were 12.9 and 5.5 per cent for the forage- and concentrate-fed groups respectively. Statistical analyses showed significant ($P<.05$) and highly significant ($P<.01$) differences between groups of bulls for non-grazing and grazing activity, respectively. Another criterion that confirmed the lack of activity in the concentrate-fed group was the number

TABLE 59.—SUMMARY OF DATA ON MEASURES OF ACTIVITY: GRAZING AND NON-GRAZING EXERCISE*

	FORAGE AD LIB	CONCENTRATE AD LIB
Grazing Exercise		
Hours observed, total†	40.5	40.5
Animal observations, total	2268	1620
Grazing observations	576	195
Percentage	25.4	12.0
Non-Grazing Exercise		
Hours observed, total†	41.25	41.25
Animal observations, total	2310	1650
Exercise observations	298	91
Percentage	12.9	5.5

*Study involved 10 bulls in lot fed concentrates and 14 bulls in forage-fed lot.

†Observed from daylight (6:00 a.m.) to dark (7:45 p.m.) for three consecutive days in September.

of animals that required foot trimming. Only three feet had to be trimmed in the group fed forage while 28 required trimming in the concentrate-fed group. With dairy bulls, Flipse and Almquist (1961) reported that bulls continuously fed a high energy ration developed weaknesses of the feet and legs and lowered sexual activity during the third and fourth year of an experiment.

LEVEL OF FEEDING IN BULL PERFORMANCE TESTS

The findings of the Florida researchers cast doubt on the advisability of feeding high concentrate diets for maximum gain during performance tests which extend beyond 12 to 15 months of age or during the fitting of beef bulls after a performance test for sale to commercial breeders. Full feeding concentrates not only cost $96.57 more but also caused physical weakness of

the bulls due to inactivity. This left them prone to injuries and could have made their eventual adaptation to ranch pasture conditions unnecessarily difficult.

A recent review of literature by Gregory (1965) on the performance testing of beef cattle emphasized the need for research. The effect of excessive fattening on subsequent reproductive performance is of especial interest because the fattening of sale bulls at performance test centers and on registered cattle farms has increased rapidly since 1960.

In performance tests, weight gains are recorded from weaning to ages varying from 12 to 20 months. Properly conducted testing programs are highly recommended by cattle geneticists who have learned that the ability of cattle to gain weight is an inherited characteristic. To illustrate the lack of knowledge regarding precise feeding methods for bull performance tests, it should be pointed out that:

1. Bull performance tests were started to find bulls which gained weight faster than other bulls under identical test and pre-test conditions. To get a true comparison of gainability, all bulls must enter a test with the same chances to gain. This almost restricts performance testing to "within herd" tests on bulls which were raised together, weaned at the same time and fed similarly.

2. Cattle breeding specialists have always discouraged the comparison of results (average daily gain on test and/or lifetime average daily gain) of bull performance tests conducted on *different ranches or in different* bull test centers. The obvious reason for such action was that feeding and management practices, especially the pretest handling of bulls, was sure to be different.

3. Proponents of bull performance testing did not specify a high-concentrate feeding program designed to obtain maximum weight gain but specified only that all bulls should be provided free access to the same feed.

A trend toward the use of high-concentrate diets and confinement feeding to get maximum gains in bull performance tests is not based on research findings; actually, the cost of such feeding programs is higher and the danger of physically handicapping the bulls is greater when compared with the ad lib feeding of forage and a limited concentrate supplement in large lots or pastures. Koger and Knox (1951) stated that "growth of

beef cattle prior to feeding age was positively correlated with gain in the feedlot"; that "when environment is constant for different animals, there is a positive relationship between gains made at different periods (ages)"; that "from a practical viewpoint, adaptability to range conditions, as measured by growth, showed a positive correlation with feedlot gain." Their research would indicate that the full-feeding of adequately supplemented forage diets in performance tests would effectively select bulls with the ability to gain fastest on either high-forage or high-concentrate diets. Warwick *et al.* (1964) in a study of twin beef bulls fed on high- and low-concentrate rations stated, "the results suggest that the safe procedure would be to select beef breeding stock under an environment similar to that in which their descendants would be produced commercially." In the Southeastern Gulf Coast states, most beef calves are raised to weaning on pasture and are grown to maturity or desired feedlot weights on pasture or high forage diets. This situation plus the high cost of concentrate feeds virtually dictates that performance testing of beef bulls in this region be done on high-forage diets. If it became necessary to measure inherited ability to fatten quickly on high-concentrate diets, a companion test (concurrent with bull performance test) with half-brother steers grown on a high-roughage diet but finished on a high-concentrate diet would be preferred. The latter also affords the opportunity to evaluate carcasses. Because a performance test record of a bull's average daily weight gain has less value than a carcass test record of his gain of edible lean, fat, and bone, many organizations sponsor carcass tests in conjunction with feeding performance tests as an additional means of identifying superior herd sires.

"Letting Down" Fitted Bulls

Prolonged stress may be endured in "letting down" excessively fat bulls by the usual practice of restricting them to pasture or other forage. The catabolism (removal by utilization) of excess deposits of body fat presents a need in the diet for other feed nutrients, especially protein, soluble carbohydrates, minerals and vitamins. These nutrients are not abundant in pasture grass which has been frosted; consequently, bulls being "let down" in the fall or winter months should be offered a limited quantity of supplemental feed in addition to forage to ensure an active rumen microbial fermentation, the microbial synthesis of B-complex

vitamins, normal levels of plasma protein, and the maintenance of operation within the body tissues of the tricarboxylic acid cycle by which depot fat is converted to energy, carbon dioxide, and water. In the absence of these nutrients, ketosis (acetonemia) and other diseases of nutritional origin may develop and affect reproductive performance.

UNDERNUTRITION

Undernutrition of beef bulls is not likely to occur except during the breeding season when the increase of sexual activity limits the time available for herd bulls to obtain enough pasture forage to maintain body weight. Ironically, the limited research which has been reported on the underfeeding of beef bulls has been done with calves and yearlings. Several extensive studies of the effects of undernutrition of dairy bulls have been reported but few include data on mature bulls. Furthermore, most of these studies have reported only the effects of level of feeding rather than the specific nutrients in the complex of undernutrition which are responsible for failures in reproduction. The application of these research findings to beef cattle ranch situations would have to be done prudently.

It is generally believed that undernutrition affects the reproductive performance of bulls in at least three ways: abnormal mating behavior due to weakened physical condition, subnormal semen quality associated with changes in tissues of sex glands, and delay in attainment of puberty.

ABNORMAL MATING BEHAVIOR DUE TO WEAKENED PHYSICAL CONDITION

In experiments with Angus yearling bulls, Meacham *et al.* (1963) compared adequate and low protein diets. Because feed intake was depressed by the low protein diets (less than 2 per cent crude protein), the effect of the low protein diet was actually protein-calorie undernutrition. Libido, as measured by allowing individual bulls ten minutes with a heifer in estrus, declined in the protein-calorie deficient bulls. The decline in libido, as seen in slowness to mount and mate, progressed in association with increasing physical weakness and emaciation. Near the end of each experiment, the protein-calorie deficient bulls showed little interest in the heifer. The authors acknowledge difficulty in differentiating between physical weakness and endocrine distur-

bance as the causative factor for the libido decline; however, it was evident that libido was adversely affected sooner than semen production. In fact, motile sperm cells were being obtained by electroejaculation from most of the deficient bulls after the decline in libido and up to the point of death from starvation. The authors indicate that libido may be the limiting factor in a bull's reproductive performance under conditions of severely reduced protein-calorie intake accompanied by a large weight loss.

SUBNORMAL SEMEN QUALITY ASSOCIATED WITH CHANGES IN TISSUE IN THE SEX GLANDS

Meacham *et al.* (1964b) with beef bulls and Bratton *et al.* (1959) and Van Denmark and Mauger (1964) with dairy bulls reported that protein-calorie deficient diets caused retardation in growth and some degeneration of the reproductive tissues.

When compared with similar bulls fed adequate diets, Meacham *et al.* (1964b) reported that protein-calorie deficient bulls had: (1) smaller secondary sex glands (seminal vesicles, Cowpers and prostate glands) and a smaller content of secretory tissue, an indication of reduced activity; (2) smaller amounts of interstitial tissue in the testes, an indication of reduced production of testosterone; (3) thinner germinal epithelium containing fewer layers of germ cells in the seminiferous tubules and (4) smaller concentrations of fructose and citric acid and less 5-nucleotidase activity in the semen, all probably being expressions of reduced testosterone production (Shirley *et al.*, 1963). Others (Flipse and Almquist, 1961; James, 1950, and Olson, 1952) also reported adverse effects of a low energy intake on semen volume and motile sperm output, especially during the early weeks of semen production. On the other hand, Mann and Walton (1953) noted that underfeeding a five-year-old Dexter bull for a 23-week period to obtain severe weight losses failed to depress motile sperm production or volume and changed only the composition of accessory gland secretions.

Unlike the finding of Van Denmark and Mauger (1964) with dairy bulls which had been underfed for a longer period of time, 8 to 46 weeks of age, Meacham *et al.* (1964b) found that the retarded or degenerate morphology of some of the reproductive tissues was not permanent and was corrected by offering the yearling bulls an adequate diet. Likewise, within 6 weeks after return to the adequate diet, semen concentrations of fructose

and citric acid and 5-nucleotidase activity had increased markedly. A more rapid recovery of the secondary glands than the germinal epithelium was indicated by a rapid increase in semen volume and motility but no increase in sperm concentration.

Delay in attainment of puberty

The effect of a restricted nutrient intake, especially protein and total digestible nutrients (energy), by young bulls has been shown by extensive investigation (Van Denmark and Mauger, 1964; Flipse and Almquist, 1961; Flipse *et al.*, 1953; Bratton *et al.*, 1959 and 1961; Davies *et al.*, 1957; James, 1950; Olson, 1952; Baker *et al.*, 1955) to retard growth, decrease rate of development of the testes, increase age at which motile spermatozoa are first produced, and delay expressions of sexual interest. Restoration of full feeding provided complete recovery of reproductive performance in most cases of underfeeding during the first two years of life. Exceptions were bulls which had been underfed for 46 months before restoration to an adequate nutrient intake (Van Denmark and Mauger, 1964) and severely underfed bulls (Meacham *et al.*, 1964b).

In summary, undernutrition in early life may delay the initiation of semen production in bulls while overfeeding in later life may decrease libido and physical strength. The need for further research to broaden our understanding of the effects of undernutrition and overnutrition on reproductive performance in bulls is increasingly becoming evident. At the present time it is difficult to point to improper nutrition as the direct cause of impaired fertility in mature beef bulls, yet reports of a high incidence of low fertility among beef bulls are common. The confusion surrounding the role of nutrition stems from a lack of knowledge about specific nutrients as essential factors for fertility.

14

E. W. SWANSON

Level of Feeding and Mammary Development

The problem of the low milk producer is present in many beef herds. A rather common experience is for an excellent type, large, fat heifer to yield a small, slow-growing calf which finishes at weaning in the lower half of the calf crop. When this occurs, the breeder questions the advisability of keeping either the heifer or her calf, because he fears the poor growth trait may be inherited. The major cause of the deficient growth is also assumed to be the poor lactation ability of the heifer. Thus, a question is raised, in the breeder's mind, regarding the compatibility of rapid growth, as exemplified in the heifer, and good lactation, which was not obtained from the heifer. He may also assume that the heifer has an inheritance for poor lactation because a heifer in such good physical condition certainly should have milked well if she had possessed an inherited potential for good lactation.

The heritability of growth efficiency and lactation has been well established. The bulk of the evidence indicates, furthermore, that they are inherited independently. This means that a breeder could select successfully for one of these factors alone. That is, lactation efficiency could be stressed to the exclusion of body growth and size—which might result in high milk yields from moderately sized or small type cows. This has been achieved between the dairy breeds. The Jersey breed, for example, has small calves which grow at a slow rate, yet many Jerseys have developed into mature cows weighing 1,000 pounds which are capable of producing 15,000 to 20,000 pounds of 4 per cent fat equivalent milk yearly. Research has also shown that, with equal

lactation efficiency and other factors, the larger the mature size of the cow the more milk it should produce. However, selecting dairy type cows *solely* on the basis of *size* will not increase the lactation efficiency or average milk yields, and could possibly result in a lowering of lactation potential. In fact, if the lactation yield were ignored and efficiency of body growth and weight gain stressed, it would be possible to develop a beef type breed from present dairy stock which might yield no more milk than is now common within the present beef breeds. It should be possible, also, to increase lactation of beef breeds by appropriate selection whenever this is desirable.

The importance of lactation in a profitable beef cattle operation has been stressed in practically every study of factors which affect quality of calves and efficiency of production. The most important factor affecting net income in a calf raising and feeding operation has been found to be weaning weight of calves. Weaning weight, in turn, is influenced more by the dam's milk production than by any other factor. Therefore, all factors, both environmental and hereditary, which affect milk yield of beef cows are of first importance.

A common assumption is that the most rapid growth rate is the most desirable growth rate, and this is true if growth or body gain is the major objective. However, if production of large calves at weaning is your major objective, of what value was the rapid growth rate of the mother which yields the calf? A small heifer that is a good milker may yield a larger weaned calf than a large, fat heifer of lower lactation ability. The heifer passes to the calf part of its inherited body growth characteristics and feeds the calf with all of its milk. For the full growth of the calf, both are important, but the milk is of greater importance in the first year. For this reason it is essential that successful beef breeders know the effect of growth rate and fattening upon lactation ability of heifers. It has been found that growth rate can influence milking ability of heifers later in life.

The relationship of rapid growth and poor lactation was first brought to my attention by a Missouri experiment (Herman, *et al.*, 1948) which was designed to produce "supergrowth" of Holstein heifers. These heifers would have reached normal mature size at two years of age and were expected to milk much better than normal heifers because of their super-adequate rearing rations. After two dozen of the supergrowth heifers had

calved and failed to milk as well as contemporary control heifers, this investigation was terminated and considered a failure. Certainly, no dairyman wants to use large quantities of extra feed just to get a large cow which will not milk as well as an average-sized one. The observation was made that the supergrowth heifers during lactation were heavy and coarse in conformation and that their udders were flabby. It was also noted that their second and third lactations were disappointingly low.

The significance of the above experiment to beef breeders would be obvious if one could be sure that the control heifers and fattened heifers had been originally equal in lactation potential. Both control and fattened heifers were purebreds from the University of Missouri herd. The supergrowth heifers had been reared similar to the way better managed beef calves are reared. They had received about as much whole milk and concentrates as they would consume consistently and only the finest quality roughage. Their bodies were round and fat, and they were broad across the withers. They seemed to be in excellent health. They were bred, conceived readily at fairly early ages, and calved without difficulty at about two years of age. There seemed to be no reason to suspect that their fast, fat growth was in part responsible for their low milk records; so a question about their actual inherited lactation ability persisted.

The next significant development in studies of the effect of growth on lactation was the use of identical twins in Sweden and Germany. European geneticists had demonstrated that they could accurately identify identical twin calves and that if they were fed and managed alike that their lactations were unusually alike. This is true because they are exact duplicates genetically, so their inherited lactation abilities were equal. Another surprising observation was that if one twin were underfed and its mate were overfed during growth they, too, milked almost exactly alike (Hansson, 1956a). A combination of two experiments with 17 pairs of Swedish identical twins showed that the highfed heifers averaged 1,037 pounds in weight and yielded 6,787 pounds of milk; the lowfed heifers averaged 831 pounds in weight and yielded 6,418 pounds of milk (Table 60). These results led Dr. A. Hansson of the Animal Breeding Institute of Sweden to surmise at first that lactation ability of cattle is a very firmly inherited factor that is not influenced significantly by rather wide differences in rearing intensity.

However, another explanation was considered. It has been well accepted that poorly fed heifers would not milk as well as those normally fed. Could it be that in these experiments neither the highfed nor the lowfed heifers had yielded as much milk as normally-reared heifers should have? This question was soon put to the experimental test at several stations.

At the University of Tennessee we first conducted a comparison of supergrowth and normal identical twins (Swanson, 1960). Seven pairs of twins, mostly Jerseys, were used. One of

TABLE 60.—GROWTH AND LACTATION COMPARISONS OF SWEDISH IDENTICAL TWIN HEIFERS REARED ON ABOVE NORMAL AND SUBNORMAL RATIONS

EXPERIMENT	1 TO 27 MO. FEED*	CALVING WEIGHT	FIRST LACTATION MILK	FAT
	(Units)	(lb)	(lb)	(%)
I (9 pr. twins)				
High	3,705	1,003	6,994	3.7
Low	1,928	766	6,409	3.6
11 (8 pr. twins)				
High	3,468	1,076	6,556	3.9
Low	2,196	904	6,428	3.8
Avg. Both Exp.				
High	3,593	1,037	6,787	3.8
Low	2,055	831	6,418	3.7
Low/High (%)	57	80	95	97

Source: Hansson (1956b).
*Normal feed unit consumption would be about 2,800 units.

each pair was fed from about four months to two years of age all of the grain it would consistently clean up plus a limited amount of hay. The other twin was fed only roughage after 10 to 12 months of age. These differences in rearing resulted in fat heifers weighing 899 pounds compared to reasonably lean (normal) heifers weighing only 683 pounds at two years of age. Typical appearance of the pairs at 14 months and two years of age are shown in Figures 11 and 12. Growth curves and the average daily milk yields of these heifers are shown in Figure 13. In the first lactation, the fattened heifers averaged only 3,397 pounds of milk compared with 4,005 pounds of milk from the normal twins. Thus, the overfed heifers which exceeded their mates 33 per cent in weight were able to produce only about 85 per cent as much milk as normal (Table 61). In second lactations

TABLE 61.—SUMMARY OF EFFECTS OF SUBNORMAL AND SUPERNORMAL REARING ON SIZE AND LACTATION IN TWO EXPERIMENTS WITH TENNESSEE IDENTICAL TWINS.

	Body weight at first calving (lbs.)	First lactation		Second lactation	
		No. days milked	4% fat milk (lbs.)	No. days milked	4% fat milk (lbs.)
Expt. I (7 pr. twins)					
Fattened	964	186	3,397	177	4,043
Normal	727	206	4,005	197	4,366
Fat/Normal, %	133	90	85	90	93
Expt. II (6 pr. twins)					
Subnormal	582	259	4,117	284	6,346
Normal	743	264	4,745	284	6,119
Sub-N/ Normal, %	78	98	87	100	104

five of the pairs averaged 4,366 pounds of milk by the normal twins compared to 4,043 pounds by the fattened twins. Although the fast-grown heifers had not all attained normal lactating ability by the second lactation, two of the five were equal to or above their mates by this time.

The results of comparing overfed and normal twins were so significant that further effort was made to discover the best method of rearing heifers to preserve or develop full lactational ability. Underfeeding of heifers is widely prevalent on dairy

FIGURE 11.—Two representative pairs of identical twin heifers comparing fattening and rapid growth with normal rearing on roughage. Left—at fourteen months the fattened twin averaged 70 pounds heavier. Right—at two years the fattened twin averaged 216 pounds heavier than normals.

farms, and, although it was believed to be a poor practice, an experiment with identical twin heifers was set up to compare normal versus underfeeding (Swanson and Hinton, 1964). Six pairs of twins completed the test. The normal twin was fed only roughage after 10 to 12 months of age, and the underfed twin was fed one-half to two-thirds as much as the normal one. This resulted in two-year-old weights of 743 and 582 pounds for the normals and subnormals, respectively. Two representative pairs of twins from this experiment are shown in Figure 14. The first

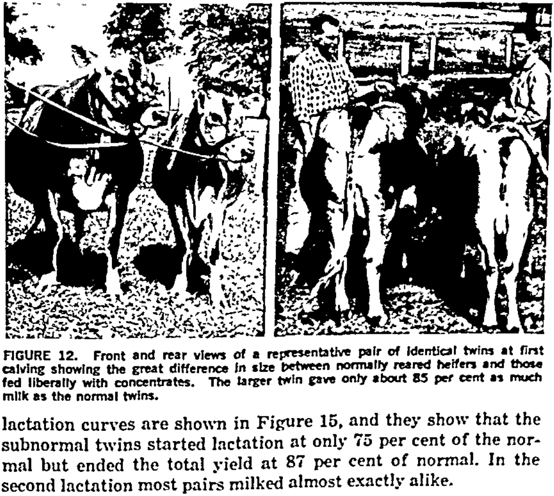
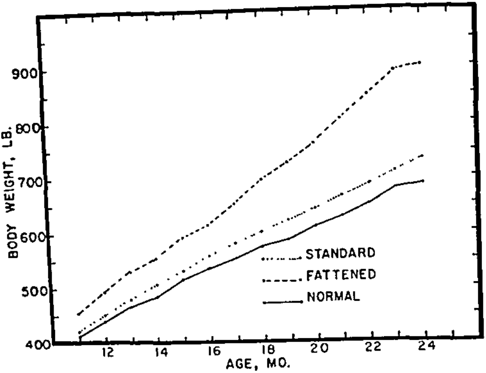


FIGURE 12. Front and rear views of a representative pair of identical twins at first calving showing the great difference in size between normally reared heifers and those fed liberally with concentrates. The larger twin gave only about 85 per cent as much milk as the normal twins.

lactation curves are shown in Figure 15, and they show that the subnormal twins started lactation at only 75 per cent of the normal but ended the total yield at 87 per cent of normal. In the second lactation most pairs milked almost exactly alike.



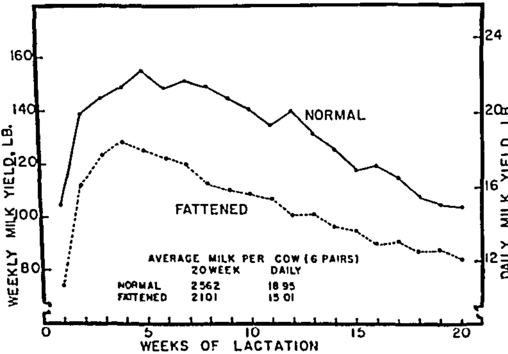


FIGURE 13. Top—average growth curves of fattened and normal identical twins. Difference in feeding began at 4 to 6 months. Normals ended slightly below breed standard weights. Bottom—average first lactation curves of identical twins comparing normal rearing with rapid growth and fattening. Both groups were fed adequately and alike during the lactation.

Experiments are now in progress at the University of Tennessee (Swanson, *et al.*, 1965) which indicate that considerable variation in growth rate in the normal to low-normal range will have no effect on lactation if the feeding level in the two to three months before parturition is liberal. Eight pairs of identical

FIGURE 14. Two pairs of twins at the start of their first lactations, representative of the group used to compare underfeeding from four months to first calving with normal rearing. The underfed twins started lactation at about 75 per cent of the normal yield.

twins have now completed or are well along in lactation on this test. Up to 12 weeks before first calving, one of each pair was restricted in feed to about 70 per cent of normal while the other twin received grain and hay according to normal feeding practice. During the last 12 weeks prepartum the well grown twins continued to receive all of the good hay they could eat, but their

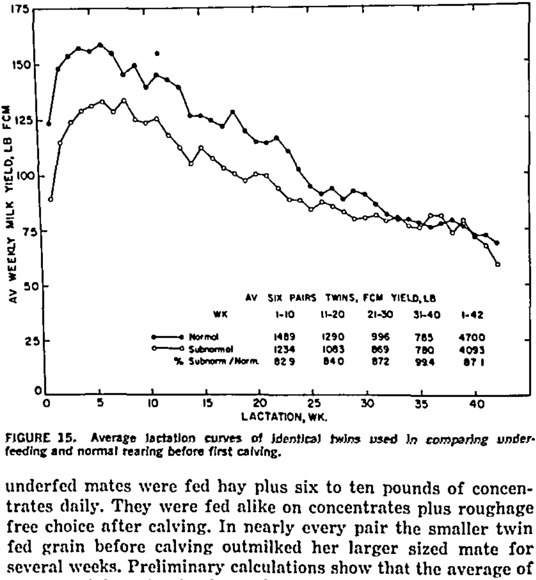


FIGURE 15. Average lactation curves of identical twins used in comparing underfeeding and normal rearing before first calving.

underfed mates were fed hay plus six to ten pounds of concentrates daily. They were fed alike on concentrates plus roughage free choice after calving. In nearly every pair the smaller twin fed grain before calving outmilked her larger sized mate for several weeks. Preliminary calculations show that the average of the first eight pairs for 32 weeks was 5,273 pounds of milk for the larger controls and 5,574 pounds for the slower growing twins.

Results quite similar to those with the Tennessee twins have also been reported by Hansson with Swedish identical twins over a range of five controlled rates of growth. The differences in

feeding during growth were terminated at 25 months of age, and the heifers calved at 27 to 30 months; so all were fed alike and adequately for two to five months before calving. A summary of these results is presented in Table 62. The results show that underfeeding as much as 40 per cent below normal in the early growth period did not depress lactation under these conditions. On the other hand, overfed heifers receiving twice the feed of the underfed group during the early growth period were definitely

TABLE 62.—GROWTH AND LACTATION RESPONSES OF IDENTICAL TWIN SWEDISH HEIFERS COMPARING FIVE FEEDING LEVELS FROM SIXTY TO 125 PER CENT OF NORMAL

GROWTH PERIOD FEED PLANNED	1 TO 25-MO. FEED CONSUMED	1 TO 19 MO. DAILY GAIN	36-WK. MILK YIELD	MILK YIELD PER CENT OF NORMAL
(% of Norm)	(Units)	(lb)	(lb)	(%)
60	1646	1.0	6857	103
80	2137	1.2	6919	104
100	2667	1.4	6635	100
120	3111	1.5	6305	95
140	3348	1.5	5661	85

Source: Hansson (1956b).

subnormal in lactation, averaging only 85 per cent of the normal twins' yield.

Several other experiments have indicated that overfeeding during growth either does not enhance lactation or may actually depress lactation. Reid *et al.* (1964) at Cornell reported that 33 trios of Holstein heifers reared on low, normal, or high levels milked about the same in the first lactation; but in second, third, and fourth lactations the high group averaged slightly below the others. Eskedall and Klansen (1958) in Denmark reported that 122 Jersey heifers reared at low, normal, and high rates produced in their first lactations 381, 363, and 350 pounds of milk fat, respectively. The normal and low heifers were fed some concentrates for six weeks before calving, yet they were still smaller in body size than the high group at calving. Stahl and Mudra, (1961) in Germany compared normal rearing with two levels of subnormal rearing in which the underfeeding continued through two lactations. Average lactation milk yields of the lowest subnormal group were 6,090 pounds compared with 6,305 pounds by

the normals. Crichton *et al.* (1960) in England compared the effects of four different rearing combinations on lactation, using 18 pairs of identical and six pairs of non-identical twins. All groups were fed adequately during lactation. The two groups fed low rations in the early growth period yielded slightly more (6,166 lb. and 6,156 lb.) milk in the first lactation than the two groups reared early on high rations (5,998 lb. and 5,359 lb.).

Cattle are not the only animals in which supergrowth can limit lactation. Sykes *et al.* (1948) reported that fat rats failed to raise their young as well as rats which were kept lean before parturition. Swanson and Spann (1954) confirmed these observations with rats and noted that the pups from the fat rats were actually starving because of inadequate milk. General recommendations in swine and sheep husbandry, (Morrison, 1956) warn against having sows or ewes in very fat condition at farrowing or lambing. Records of milk yields from these species have not been correlated with body condition in enough experiments to be sure that the recommendation to avoid fattening is related to lactation. However, the implication is that leaner sows and ewes make better mothers and produce plenty of milk.

The bulk of the evidence is quite definitely against fattening in the early growth period if full lactation potential is to be developed. The reasons why fattening limits lactation are not so definite. Certainly the cause of the limited lactation of the fast growing, fattened animals should not have been any nutritional deficiency, as it is not logical to associate very rapid growth with nutritional deficiencies. In most of the experiments cited above, excess vitamin, mineral, and protein supplements had been provided both overfed and underfed animals to avoid deficiencies of any of the nutrients known to be required except energy. Furthermore, when a known energy deficiency was purposely developed, it did not prevent normal lactation if adequate nutrition were initiated about two months before calving.

The best clue we have to the reason for supergrowth depressing lactation is the effect it appears to have on the mammary gland. The mammary glands of four of the Tennessee twin pairs, comparing fattened and normal heifers, were fixed, stained, and cut into slices. All glands from the normally reared heifers were essentially normal in gross appearance and structure. Three of the four glands from the fattened twins were abnormal in internal structure. The outer areas of what should have been milk

secreting tissue were filled with cysts or cavities (Figure 16). These spaces were connected to the ducts of the normal part of the mammary gland, indicating that they were probably part of the gland which failed to develop properly. The fattened twins which differed most in lactation from their normal mates also had the greatest degree of abnormal udder structure; so there

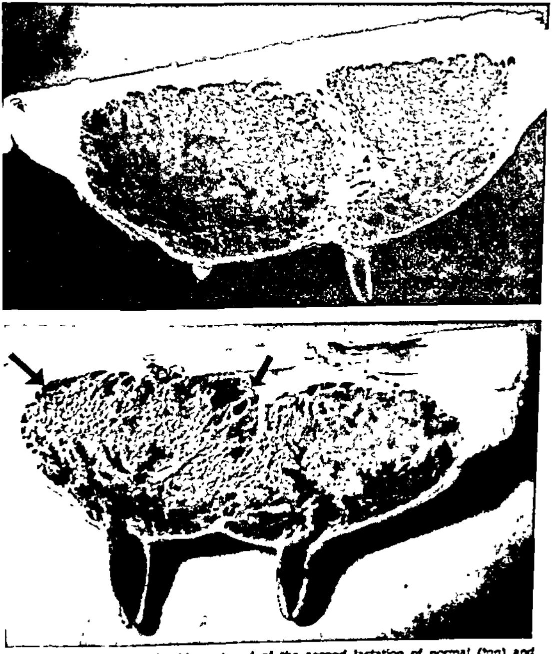


FIGURE 16. Sections of udders at end of the second lactation of normal (top) and fattened (bottom) identical twin heifers. Note the larger area of dense secretory tissue in the normally reared twin's udder and the open, undeveloped spaces (arrows) in the gland of the fattened twin (bottom).

was an association between the udder deficiency and the lactation deficiency.

The mammary glands of the calf at birth consist of not much more than small teats and tiny cisterns of the glands just above the teats. The beginnings of the duct system are around the periphery of the rudimentary gland cistern, similar to buds on the trunk of a grapevine. These buds can grow upward into the loose connective tissue of the immature udder, and, as the heifer matures, the duct system expands in this manner until its branches occupy an area of 20 to 30 square inches on each side. The udder is also the site of deposition of a mass of fat in calves which are overfed. The fat replaces the loose connective tissue from above in competition with the mammary growth which is developing from below. The poor or abnormal growth of mammary gland secreting tissue into the fat-packed udder area of fattened calves may be due to a physical interference, or it may be due to an interference with the normal movement of hormones required for normal gland development into the area. It has been shown experimentally that abnormal hormone treatment can produce abnormal mammary glands which are deficient in lactation, so it is quite possible that the true cause of deficient development of fat mammary glands is associated in some way with hormone action.

Overfeeding in one generation of heifers could result in underprivileged sucklings in the next generation. To avoid this it would be necessary to separate breeding stock heifers from the fattening group at an early age, e.g., four to five months, and from that age on bring them along at a moderate growth rate, avoiding fattening as much as possible. The costs in producing such heifers would be lower, and the profits from their calf crop should be higher. Another advantage to avoiding fattening of young beef heifers to allow for normal lactation potential to develop, is the increased genetic accuracy one could depend on in culling dams because of poor calf gains. A cow which fails to lactate because her udder hasn't had a chance to develop properly may be a genetically acceptable milker; but one that can't do the job after optimum rearing is undoubtedly an inherently poor milker. If from generation to generation continued improvement of cows in selection for lactation is to be effective, development of lactation potential should not be inhibited by either very fast or unusually poor growth.

Although these observations and theories indicate that the intensity of *early* growth of the calf can affect mammary development, what about heavy feeding or fattening in the *later* growth period? Assuming that the above explanation is correct, rapid growth or fattening after the mammary gland has been developed normally should not depress lactation potential. In the usual course of events, the mammary gland develops most rapidly in the first few months after the heifer conceives. By the sixth month of gestation the internal structure of a heifer's mammary gland shows nearly complete development. Fattening after this stage should have very little effect on the mammary gland, whereas a heifer which is very fat at time of breeding and kept fat throughout gestation may be expected to have a lactation deficiency due to improper gland development.

A number of experiments (Hancock, 1953, and Broster *et al.*, 1964) have shown that heifers in average body condition, fed liberally during the two to three months before calving, usually milk at a higher rate than those fed more restricted rations—such as roughage only. Concentrate feeding in the prepartum period will produce some fattening, but at this stage it cannot interfere with mammary development. The excess body condition, however, is available for milk formation in cows of high lactation potential. Liberal feeding of the prepartum cow or heifer is a common practice in dairy husbandry because it results in high levels of initial lactation.

From a practical standpoint in beef cattle operations, the possible effects of lactation depression due to heifer growth and fattening in respect to the level of milk yield presently obtained should be considered, as it may affect the weaning weight of the calf. In the fattened dairy type identical twins cited above, the average deficiency in lactation was about 600 pounds in the Tennessee study and 1,000 pounds in the Swedish study. Within pairs, differences were as high as 2,400 pounds of milk and differences were just as large in low producing twins as in the better producers. A beef heifer with a potential normal yield of 2,500 pounds may end up with only 1,700 pounds of milk or less for her calf if she had been kept too fat in early growth. In this range of milk yield, the gain of the calf would be about 70 pounds below normal. If, on the other hand, the normal yield of a beef heifer were 4,000 pounds of milk, even a 1,000 pound reduction would allow for a very desirable calf weaning weight.

How much milk is presently being produced by our average beef cows? Several carefully collected records have been made of milk yields of beef cows under practical conditions. Neville (1962) reported from Georgia that 61 Hereford cows over a three-year period average 2,256 pounds of milk in a 240-day lactation. Gifford (1953) reported that Arkansas cattle under pasture conditions yielded the following: 57 Herefords averaged 1,303, 11 Angus averaged 1,972, and 8 Shorthorns averaged 1,983 pounds in 240-day lactations. Milk yields of 7 Angus cows, reported from Wisconsin by Cole and Johansson (1933), which were milked twice daily throughout their lactation for four lactations averaged 3,100 pounds of milk. The latter information indicates that milk yields of beef cows suckling calves might have been higher if greater consumption of the milk by the calf had occurred early in lactation. The inability of the calf to consume the cow's full potential milk yield in the first month of lactation results in a decrease of yield to a practical maximum equal to the calf's appetite. Milk left in the udder accelerates the drying off process. The low production of many of the cows which have been studied, however, was not due so much to short lactations as to very low initial lactation levels. Several of Gifford's cows, for example, averaged less than four pounds of milk per day for nearly eight months, and the maximum daily yield of one-fifth of his cows was less than 6.5 pounds.

How great a milk yield should we strive to attain in our beef cows? Obviously it is unnecessary to have a cow capable of producing 50 pounds daily if the calf will not take more than 10 or 15 pounds. However, if the calf could use up to 20 pounds and the cow can provide only five or six pounds, the potential rate of gain of the calf will not be achieved. Records of hand-fed calves show that they can often consume one-fifth of their body weight daily as milk alone. Numerous research reports have emphasized the importance to calf growth of an abundant milk supply from the dam. Gifford (1953) showed that calves from cows which in their first month of lactation gave more than 13 pounds of milk daily (averaging 15.6) weighed 121 pounds more at 240 days than calves from cows averaging only 5 pounds of milk per day. Furthermore, this growth advantage persisted in later life. He found that of heifers kept in the herd to 36 months of age, those from the better milking dams averaged 109 pounds heavier than those from poorer milking dams. This observation indicates

that a desirable growth rate and a moderate lactation potential in beef cattle are not incompatible, but may, in fact, be complementary.

The actual amount of this "moderate," desirable milk yield has been indicated from analyses made by Neville (1962) to be at least 2,500 pounds in 240 days. Below this level, calf gains were 7 to 8 pounds for each 100 pounds increment of milk, but above this, the increased calf gain was only about 4 pounds per 100 pounds additional milk. Thus, a cow giving 3,000 pounds of milk may have a calf weighing only 20 pounds more than the calf from a 2,500 pound producer; but the calf from a cow giving 2,000 pounds of milk would weigh 40 pounds more than one from a 1,500 pound producer at 240 days. Beef cows with the highest milk yields can be expected to wean the largest calves, but at yields much over 2,500 to 3,000 pounds, part of the milk is used by the calf in place of other feed which might be available at the same time. Cows yielding 2,500 pounds of milk in 240 days will be milking at the rate of 16 to 18 pounds daily in the first month, and even potentially higher yielding cows can give only as much as the calf will take, which is usually less than 20 pounds daily in the first month. The milk supply then decreases gradually, but the calf's appetite increases as it grows and develops; so calves start to supplement their milk diet at an early age with grass or grain.

Another method of determining the yield of milk desired from beef cows would be to establish the gain in calf weight desired. On the average, 10 pounds of milk will produce one pound of gain in calf weight. Therefore, a gain of 240 pounds (1 lb/day) would require 2,400 pounds of milk if the gain came entirely from milk. Usually from one-third to one-half of the 240-day gain can be obtained from feeds other than milk; so cows producing 2,400 pounds of milk would have calves gaining 320 to 450 pounds, depending on the quality of the supplemental feed. If a 500 pound gain were desired, a yield of about 3,000 pounds of milk would be desirable, with additional good supplemental feed.

The level of milk yield which one should strive for in beef cattle, therefore, is about 2,500 to 3,000 pounds in eight months, which should give under good feed conditions 520 to 575 pound calves at weaning. From survey studies which have been made, the majority of beef cows and heifers are not attaining this level of milk production. This means that any environmental block to

the achievement of full lactation potential will likely reduce calf growth and profits significantly, as it may change a barely adequate milker to a definitely inadequate one. Therefore, avoiding overfattening of beef heifer calves to be kept for replacements is worthy of most careful consideration. The most desirable replacement heifers will be those fast-growing calves from desirable type cows which are heavy milkers. These calves are also the ones most likely to get too fat in early growth; so a decision should be made early enough to reduce their feed intake in time to prevent damaging their lactation potential.

Summary

The primary inherited distinction of good beef cattle is the ability to gain weight rapidly and efficiently. In pursuing this trait the ability to yield acceptable quantities of milk may have been overlooked, for beef cows are often rather poor milkers. It is possible also, that the traits for rapid gain and good milk yield are either inherently or practically incompatible. Long time observations of breeders support the notion that very fat heifers make poor brood cows. Experiments with dairy heifers designed to produce excessively rapid growth and fattening have indicated that the lactation deficiency in such animals may not be inherited. Potentially good milkers have been turned into poor milkers consistently by overfeeding during the early growth period. Experiments with identical twins, which will milk alike if managed alike, have shown that either overfeeding or serious underfeeding during the development period results in lactations about 15 per cent or 800 pounds below normal. The lactation deficiency of the underfed heifers can be corrected simply by proper feeding, especially feeding well in the last two or three months before calving. The cause of the lactation deficiency in the fattened heifer, however, is most likely a structural defect in the developing mammary gland. This defect cannot be corrected by simply reducing the high physical condition, and it may persist in a fattened udder through several lactations. For this reason avoiding overfattening in early growth of beef heifers is an important factor in assuring optimum lactation which is required for attaining the objective of heavy weight weanling calves for market. Special management to avoid excess fattening of heifer calves may be needed because the most desirable replacement heifers are the ones most likely to grow too fat.

15

D. F. WALKER

Bull Growth, Management, and Fertility

The ability of a bull to bring about conception in cows depends upon three primary factors which are often affected by growth or management. The three factors are: the ability to breed, the desire to breed, and the formation and ejaculation of semen of satisfactory quality. A bull must possess all three qualities before he can be classified as a satisfactory breeding sire. Cattlemen observe a bull breeding a cow and may conclude he is fertile, the opinion being based upon two of the factors, ability and desire. A veterinarian may make a similar mistake by concluding a bull is satisfactory following an examination of the bull and the quality of his semen. Desire or libido may be lacking. A joint opinion by both the cattlemen and the veterinarian, of course, would cover the three aspects. Let us consider these three entities one at a time and see how they may be affected by growth and management.

find his place on the social ladder of bulls, must challenge and fight all the bulls in the herd. Under such conditions, the young bull can often end up permanently crippled.

Two factors of growth and management are involved. First, there is the problem of excessive weight. No coach would put a wrestler or boxer into the ring until he is properly conditioned. The second factor is structural strength of bone and tendon that comes with age and maturity. In short, young fat bulls should be given an opportunity to harden up and mature before being placed into the breeding herd. This letting down or hardening up must be done with care, or conditions which affect semen quality may develop. These conditions will be discussed later.

The inability to copulate because of insufficient penile length or juvenility is a very common condition observed in highly fitted young bulls. It is quite possible to produce juvenility by insufficient feeding or growing bulls, but it is necessary to reduce the ration below 60 per cent of normal (Reid, 1959). These are starvation conditions and they are rarely observed under the present system of growing and selling bulls. Sexual development is also retarded by other conditions of the young bull (Arthur, 1964). This is a much greater problem at the present time than an insufficient diet. Sexual retardation is particularly evident if the conditioning process is started during early calfhood (Arthur, 1964). Most bulls so affected with retardation will recover in about six months when placed on a normal maintenance diet. The condition tends to become permanent if bulls are kept in an overfat condition beyond the period of two years of age. This condition might be termed induced juvenility. It is important to point out that juvenility may also be inherited. When juvenility does not correct itself within six months after the let-down period begins, it should be considered inherited and the bull disposed of so as not to promote the trait further in the cattle herd (Lagerlof, 1936).

We must be conscious of a double condition: first, inherited juvenility and second, induced juvenility or sexual retardation. It is impossible to distinguish between them except by careful consideration of the entire history of the bull in question and perhaps a trial recovery period.

Another condition resulting in the inability to copulate is deviation of the penis. This condition is believed by some to result from sexual retardation. Bulls affected with deviation of the

penis are quite often satisfactory breeders during their first season. In the second season they are unable to breed because of a spiral or corkscrew deviation at the extremity of the penis. Occasionally this condition manifests itself by a sharp downward bend at the end of the penis. It has been postulated that this condition is caused by, first, a rapid growth of the body structures but a retardation of penile growth. Secondly, when the bull later is put in to service the penis is stimulated to grow but the supportive structures of the penis, the muscles and ligaments, fail to grow since their growth has terminated. This results in the supportive structures being insufficient for the size of the penis, thus causing deviation (Walker, 1964).

Libido

Sex drive is fundamentally controlled by the amount of male hormone in the general circulation. Psychological factors also play an important role. If a bull is unable to copulate, he will give up trying after a period of time. Therefore, in some cases we can say that sex drive may be associated with ability to copulate. This is evidenced by the marker bull, used in some artificial insemination practices, whose penis has been tied in by surgery. Such bulls function well for a period of time but eventually stop breeding attempts when they are not able to make sexual contact (Roberts, 1959).

It has been demonstrated that bulls weakened by starvation to the point where they can scarcely get to their feet will make an attempt to breed. This does not mean such bulls are fertile, however, since their ability to produce satisfactory semen may be greatly impaired. Only bulls that have been kept on a starvation diet since calfhood will show decreased sexual desire (Hentges, 1963).

It has been demonstrated that bulls kept on a high level of nutrition for long periods since early calfhood, show a great decrease in sexual desire. At best, they make only feeble attempts to copulate. Work done at Florida clearly demonstrates this (Hentges, 1963). Nine out of ten bulls so fed and managed were not capable of copulation, and all showed a marked decrease in sexual desire. It was the writer's privilege to examine three of these bulls, and the underdevelopment of the penis and other sex organs was identical to similar cases so commonly observed in practice.

To fully understand this condition it will be necessary to review some of the basic physiological factors involved.

The testicle has two functions. First, it produces sperm cells, and secondly, it produces testosterone, the male hormone which is responsible for sex drive and the development of the genital organs. The sperm cells are produced from the seminiferous tubules. The activity of these tubules is controlled by a hormone known as follicle stimulating hormone (FSH). The cells between the seminiferous tubules, or interstitial cells, produce testosterone. The activity of these cells is controlled by a hormone known as Interstitial Cell Stimulating Hormone or ICSH. (Nalbandov, 1964). The problems being discussed in this paper are brought about by an insufficiency or imbalance of one or the other of the two hormones. Physical condition and the nutritional level greatly affect these hormone levels (Nalbandov, 1964).

When the bull is on an insufficient diet or suffers from some condition that causes a severe loss of weight, the FSH hormone production is stopped or reduced in output, and the bull's semen quantity and quality is reduced due to degeneration of the seminiferous tubules. This could be compared to a cow decreasing milk production under similar circumstances. An insufficient diet, however, does not affect the sexual desire of the bull until it becomes extreme, or continues over a long period of time.

The phenomenon of excessive and prolonged feeding affecting the ICSH hormone, testosterone output, or the effect of testosterone, is not clearly understood at the present time. From existing evidence we are sure it does exist. The results are: juvenility and lack of sexual desire.

When bulls are put on a rapid weight gaining diet as calves, before sexual development begins, and maintained on this diet through the sexual development phase of their lives (to approximately three years of age), the result is an infertile bull. In most cases, it is too late in the bull's life to expect recovery by subsequently reducing the feed intake level (Arthur, 1964 and Walker, 1964).

Another factor that occurs in over-conditioned bulls is the deposition of fat in the scrotum. For normal sperm cell development it is necessary that the testicles be maintained at a temperature below normal body temperature. To accomplish this Nature has developed an elaborate radiator system with a built-in thermostat to control it. The testicle has a muscle attached that is re-

laxed on hot days to allow the testicle to hang away from the body, but it contracts on cold days. There is also a cooling device for the blood that flows into the testicle. This is accomplished by a network of veins that surround the artery, enters the testicle, and lowers the blood temperature before it enters the testicle. Heavy deposits of fat in the scrotum interfere with this process (Hill, 1956).

If a bull's scrotum is insulated by covering it with a sheep skin, the bull soon becomes infertile. If the sheep skin is removed after a few days the fertility will return in 30 to 60 days. If the sheep skin is left on for an extended period of time the infertility becomes permanent.

Semen Quality and Quantity

Many factors will affect semen quality, such as inheritance or disease conditions, but the common problem as related to growth and management is testicular degeneration. It has been pointed out how fat in the scrotum will bring about degeneration of the seminiferous tubules and how starting calves on a high level of nutrition will result in an undeveloped testicle (technically, this is induced hypoplasia rather than degeneration). The commonly occurring problem, however, is one of an insufficient diet, resulting in insufficient FSH hormone to maintain sperm cell development. This is observed when the fitted bull is let down in condition.

ly recognized by most cattlemen. It is common practice to select the best potential bulls as young calves and place them on a high level of nutrition until show or sale time which is at about 18 months of age. The buyer often places the young fat bulls in service immediately after purchase or simply turns them loose in a pasture to make their own way. The net loss from these two practices is quite high.

The practice of fitting bulls prior to sale is well established. Obviously, some good features are derived from this system. It enables the buyer to see the fattening potential of the bull and, in many cases, the rate of gain is available.

For a bull breeder to attempt to market his bulls without fitting them would be difficult so far as price received is concerned. The competition of fitted bulls would result in lower prices in most cases.

The problem at the present time is being handled by a guarantee from the breeder to the bull buyer. Such guarantees usually permit a six to twelve month period to allow for development of underdeveloped or juvenile bulls. Also, this allows for correction of some of the problems encountered during the let-down period. The breeder generally is the loser, except in those cases where the infertile bull is not discovered within the time limit of the contract. The breeder is often placed in a position over which he has little control and, consequently, absorbs the loss of most infertile bulls regardless of the cause.

There is no complete answer to this problem but a few suggestions are given as follows:

1. Understanding and acceptance of the problems by all parties concerned.

2. Controlled research to obtain information on the following questions:

(a) age at which the bull calf may be put on high level of nutrition.

(b) length of time bull may be maintained on high level of feeding.

(c) periodic hormone assays during this period (FSH and ICSH).

3. In the interim feeders and buyers should follow these broad suggestions:

(a) Do not start young bulls on a high level of feed intake until they have reached at least the age of six months.

(b) Maintain young bulls on a high level of feed intake no longer than ten months.

(c) Slowly reduce the ration of fat bulls until evidence of scrotal fat and subcutaneous fat has disappeared.

(d) Do not use the bulls for heavy service until they are 24 months of age.

16

J. C. BONSMA

Climatology and Breeding for Adaptation

Animal ecology is the science which explains the interaction between the animal and its total environment. In livestock production it is most essential to have a clear concept of how each environmental factor influences the animal and how we can breed animals to be better adapted to any environment. The concept of livestock ecology is explained with the diagram of a wheel (See Figure 17). The axle of the wheel is man, the most important single environmental factor in the concept of interaction between heredity and environment. The animal is the hub of the wheel and is in close symbiosis with man as a result of the fact that man has domesticated these animals. Out of the 3,000 species of mammals, only 30 different types of animals have been domesticated.

The total environment is presented by the running surface of the wheel, and each environmental factor which acts as a leverage on the animal is described by a spoke. Each spoke of the wheel has a direct influence on the animal, and the most important spoke is nutrition. In an effort to evaluate the interaction between the animal and its total environment, the animal scientist must have a clear concept of what total environment embraces, and it is necessary to indicate how the world is subdivided into different climatic zones.

The world is divided into four major climatic zones (Figure 18). The first is KEEN, regions where the atmospheric temperature never reaches a monthly average temperature of above 65°F., and where the relative humidity is usually lower than 65 per cent. An area which is cold and dry is classified as keen.

Cold and dry conditions are very unfavorable to animal life and are antagonistic toward promoting plant life. Hence, in keen climates we have very little vegetation to nourish animals, and highly productive animals cannot be maintained. In the slightly milder regions of the keen climate, it is possible to keep animals such as reindeer which live on mosses and lichens. In the keen climate we usually find certain furbearing animals which can live on fish and other nutrients obtained from the ocean or from the sparse vegetation found in those areas.

The next large climatic zone is SCORCHING. In the scorching zone, we have an average monthly temperature varying from

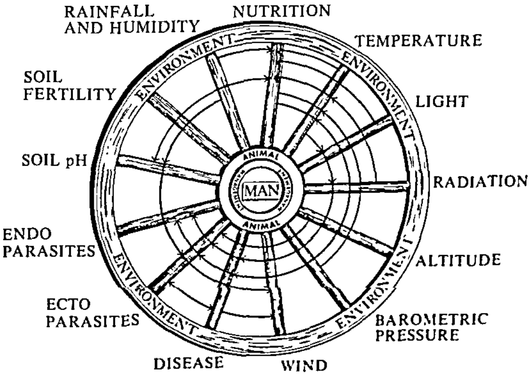


FIGURE 17. This wheel explains the concept of livestock ecology.

an area in which climatic stress on the animal is not great. All the improved breeds of livestock have been developed in those countries having a raw climate. It may be that the stimulating and invigorating climatic conditions of those areas might have had a very favorable influence on the efforts of the human inhabitants.

The next climatic zone is MUGGY, regions of the world which have high atmospheric temperatures, 65°F. and higher, and a very high humidity of 65 per cent and higher.

To understand the interaction between the animal and the en-

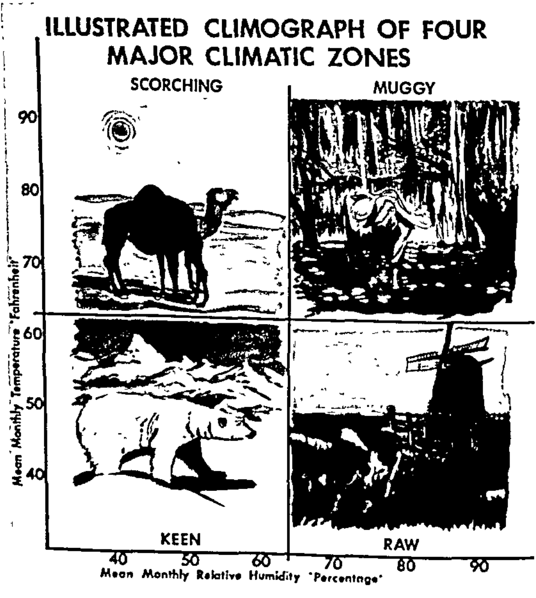


FIGURE 18. The world is divided into these four climatic zones.

vironment better, it is necessary to see various natural environments and to appreciate the climatic conditions which prevail there. Charles Darwin's writings are a constant source of inspiration and incentive to the biologist; his ideas on natural selection and on evolution are challenging. Ernst Haeckel is another scientist who stimulated my interest in ecology by showing how the ecological relationship between plants and animals plays a tremendous role in their economic success or otherwise. Haeckel is considered to be the father of the science of plant and animal ecology.

A region with a typically keen climate is the Arctic Zone where there is very little animal life except for some fish in the fiords which are not iced over; polar bears might get enough food in those areas. In the high Alps of Switzerland above the timber line, the climate is also keen and no animals can be maintained at altitudes above this line.

The Alpine pastures in Switzerland are in a high-altitude raw environment. High-altitude raw environments are also found in various parts of Europe, South America, North America and the European Continent where altitudes are above 4,500 feet, where the rainfall is usually approximately two inches per month, and where the average annual isotherm does not exceed 60°F. Such an area is very favorable to livestock production but its pasture growth is very slow although the pastures are very succulent, low in crude fiber, and high in protein. In the high altitude pastoral regions of Switzerland with its raw climate, the grazing is often communal, the pastures are harvested for hay production, and the communal cattle owners live in their huts high up in the Alps to be near their animals when storms come up rapidly. The storms are real hazards to the cattle, and human endeavor is essential to prevent heavy stock losses.

Holland is a country with a low-altitude raw climate. Some of the pastoral areas of Holland are actually below sea level. The average temperature is below 65°F.; it is cold during winter and has an average rainfall of at least two inches per month with rainfall efficiency exceedingly high. Pasture values are high as a result of slow growth, having low crude fiber content and a high protein content especially where fertilizers have been applied. A large proportion of the pasturage in Holland is on reclaimed land which is below sea level and has to be drained. In the past this was done by windmills which are now being replaced by

centrifugal pumps. The pastures in Holland are divided by shallow ditches which the animals will not jump.

Scotland is an example of a raw, low-altitude, windy climate which results in animals needing more feed for energy and having woolly coats to maintain a thermal equilibrium.

Another type of environment which can be described is the high-altitude, semi-arid climate of parts of Southwest Africa, with altitudes of 6,000 feet and higher. These semi-arid high altitude pastures do not get very cold nor very hot. The limiting factor in these areas is the unreliable, fairly low, seasonal rainfall and low vegetation density with the accompanying low carrying capacity.

Low-altitude, scorching climates are found in most of the semi-arid regions of the world such as Africa, Australia, and parts of South America. In the low-altitude, scorching climates, the altitude of the ranching areas is usually less than 2,000 feet above sea level. The average annual isotherm is above 70°F., rainfall is sparse, it usually varies from approximately 12 to 16 inches per annum and is often seasonable and unreliable. The Bushveldt and Middleveldt pastoral regions of the South African savannah country has an altitude of approximately 3,500 feet above sea level. The average annual temperature varies from approximately 63°F. to 70°F. In these regions the pastures are usually of a natural curing hay type, depending on the soil pH whether the pastures are high in protein or not.

In areas with a muggy climate, the problem is high humidity and temperature. As a result of the high humidity and high temperatures, the pastures grow and mature rapidly, are high in crude fiber, and are low in protein. Insect pests are a real hazard to the animals in muggy climatic zones. The animal has to overcome the hazard of maintaining its thermal equilibrium and the hazards associated with ecto-parasites such as ticks, mosquitoes, flies, etc. In areas with very high humidity and temperature, such as Fiji, it is almost impossible to successfully maintain the British breeds of livestock such as the Hereford, Shorthorn, Aberdeen Angus or the dairy breeds such as the Holstein or the Jersey unless appropriate shelter and nutritional conditions are provided. It is a real problem for the animal to maintain a normal body temperature in those areas.

Areas of the Southern United States, for example parts of Louisiana, Florida, and Texas, have a muggy climate. As a result

of the high temperature and humidity, the soil pH is very low, the minerals in the pastures are leached out, and in some of those areas the water table is near the surface. Such areas are quite deficient in both macro- and micro-elements. In a muggy climate the problem of heat dissipation is always more difficult than it is in a semi-arid climate.

In an attempt to understand and appreciate the influence on the animal of the climatic regions of the world and their interaction, it is essential to study animals in their natural habitat. Animal behavior and physiological reactions must be carefully observed, described, and interpreted. Adaptability phenomena in animals of particular areas must be assessed in an endeavor to utilize them in the breeding programs of domestic animals which will have to overcome climatic hazards of corresponding environments.

The polar bear is well adapted to a keen climate. Its most obvious adaptation is the white coat, with an inner heat-retaining coat and outer protective hair forming a formidable insulating coat; hence, radiation of energy from the body surface is reduced and the maintenance of the body temperature is no problem. The polar bear also has a layer of fat approximately one inch thick over its entire body which also acts as an insulating mechanism. The animal conforms to Bergman's and Allen's Law, namely that in a cold climate the animal is squarely built, has a small surface area per unit weight and has relatively short and thick extremities. In the case of the polar bear, its legs are exceedingly thick. If given a diet of fish, this animal will always select those which have the highest liver oil content to provide the most readily available abundant source of energy.

The American bison is an animal adapted to the cold savannah areas of North America, where it must overcome wind, snow, and blizzards. All the vital organs of this animal are protected by a dense outer protective coat and a very furry inner heat retaining coat. The bison also has an adaptability phenomenon as far as its reproductive organs are concerned. The testes are carried in a very small scrotum which withdraws right into the body cavity during the severe cold weather and only during springtime when warmer weather appears will the animal drop its testes in the

retaining coat. As a result of the greatly varying climatic conditions between summer and winter in the Siberian desert, this animal has a thick winter coat which sheds rapidly during spring and the animal becomes practically smooth coated during the summer months.

The Rocky Mountain goat is another animal which has adaptability phenomena, especially for climbing steep ledges and mountains. Apart from that, it has a color which makes it adaptable to the environment.

The one-humped camel of the Asian deserts is an animal adapted to the scorching climate of the desert. It has nostrils which can close when dust storms come up; its lips and tongue are very poorly supplied with nerve fibers; hence, these animals can consume fibrous and thorny desert plants such as cacti without injury to the mucous membranes of the lips, tongue, and mouth. The animal has false eyelids which can go over the eye when harassed by dust storms. The areas of the body which are in close contact with the hot desert sand have calloused pads. It is able to drink tremendous amounts of water and, by an adaptability mechanism in the digestive system, can maintain itself for several days without drinking water. The feet are especially adapted to enable it to travel over the desert. It has a well protected outer and inner heat retaining coat during winter which sheds very, very rapidly during the summer

Animals adapted to the hot, subtropical climates of the African Continent have the adaptability phenomena which conform with Bergman's and Allen's Law, namely that the tropically adapted animal has a large surface area per unit weight and the extremities of the animal; that is the limbs, tail and ears, are usually long, hence increasing the radiating surfaces of the body.

Animals which are well adapted to the subtropical environment of the semi-arid regions are the kudu and the impala. Both these types of antelope have long limbs, flat bodies, and a large surface area per unit weight.

The zebra is an animal which is really adapted to savannah country as a result of mimicry, namely dark and light areas on the body, hence, they are most difficult to see in forested areas; it is therefore more difficult for predators to see and get these animals.

In muggy areas, we find that very few breeds of livestock can be maintained. In a muggy climate such as that of Trinidad, it is

difficult to maintain any of the improved breeds of domestic cattle, and it will be necessary for mankind to do a vast amount of selection and breeding work on the water buffalo. The water buffalo is an animal which is well adapted to a muggy climate.

Domestic animals exhibit certain adaptability phenomena, due partly to natural selection and partly to selective breeding. In the north of Scotland, the Scotch Highland breed of cattle is very well adapted to that environment. In the north of Scotland the climatic conditions are very drastic. The cold, windy, and moist winds from the North Sea often blow on the cattle. The Scotch Highland breed of cattle, as a result of being continuously exposed to cold, moist winds, has an outer protective coat of long medullated hair and an inner heat retaining coat. Since the soil pH or low calcium content of the natural pasturage here is very low, these animals are very small framed. They are quite hardy and can overcome the wind. Animals of this breed which were taken to Suffolk in England, an area of Britain which is renowned for its fertile soils and good pastures, become much larger than the animals in their natural habitat. A number of purebred Scotch Highland cattle were taken to Suffolk 200 years ago. Since, they have been selected and bred pure in that environment and today the Scotch Highland cattle in Suffolk are much larger and heavier than those in Scotland. The difference in weight between bulls in the Highlands and in Suffolk is approximately 400 pounds in favor of those in Suffolk. The difference between the cows is approximately 200 or more pounds.

The Galloway breed of cattle which also originated in Scotland is another breed which is well adapted to a windy, cold climate. Animals which are exposed to really cold, windy climates usually have a long outer protective coat and an inner heat retaining coat, and are square in body conformation.

The black-faced Scotch Mountain sheep is a breed which is very well adapted to the tremendously hard climates found in the north of Scotland. What is most interesting about these sheep is that they have a very short breeding season. Those lambs which are born out of the regular six-week lambing season will usually succumb. The ewes come in heat for a very short period and are in anoestrus for the rest of the year.

The *Bos indicus* species of cattle such as the Africander of Southern Africa and the Brahmans of the Americas and Asia are well adapted to the subtropics and semi-arid regions. The

Africander is a breed which shows some very interesting adaptability phenomena; they are sleek coated, have a large surface area per unit weight, a fairly well-developed dewlap, and a sheath or navel fold. They have well-developed panniculus muscles and are usually thick hided. Downward skinfolds in the hide are indicative of a thick hide: hence, the animals have a high vascularity of hide, that is the blood flow to the hide is profuse so that the animals are well adapted to high temperatures and their hides are usually thick and fly repellent.

The most important spoke in the wheel is nutrition. That nutrition is the most important factor in the relationship between the animal and its total environment cannot be denied. Natural vegetation is dependent on rainfall, temperature, humidity, etc., and the types of animals maintained in any area are dependent in the first instance on the total nutritional level of that environment.

In 1953, an advertisement by General Mills Incorporated intrigued me. They indicated that in 1910 their pig rations were made up in such a way that a pig required 500 pounds to gain a hundred pounds in weight and that the pigs reached the hundred pound mark in five months. By 1930, as a result of improving the rations by greater knowledge of nutrition, the pigs could gain a hundred pounds in weight on 364 pounds of feed and in 1953, the pigs could gain a hundred pounds on 300 pounds of feed, and they could top the two-hundred pound mark in five months. Hence, these people concluded that as a result of the great improvement they made in balancing their rations by adding antibiotics, minerals, vitamins, and balancing the amino acids in the proper proportions, they could produce rations that could make pigs gain a hundred pounds on 300 pounds of feed. This advertisement is a half-truth. During the period 1910 until 1953, livestock breeders have changed the body conformation and the function of these animals too; hence, the improved rations were only partly responsible for the increased and more efficient weight gains on those rations.

As a result of this advertisement, the author bought unimproved native pigs in the Bantu territories of South Africa and brought them to the University of Pretoria. At Pretoria University we maintained a number of Bantu sows and a number of Swedish Landrace sows. Young pigs of the unimproved Bantu type and highly improved Swedish Landrace pigs were divided

wool of very low value. Black sheep which suffer a copper deficiency develop a white line in the black wool every time they are on a copper-deficient ration. Whenever copper is added to the ration, they produce black wool again.

It is essential in evaluating the nutritional and mineral deficiencies of areas that the cattleman should know the indigenous trees of an environment. Those areas in which Tarconanthus Camphoratus, that is a shrub indigenous to South Africa, grows naturally are usually phosphorus deficient. In all phosphorus deficient areas cattle breeders suffer severe financial losses if they do not feed phosphate supplements. Phosphorus deficiency not only causes much lower fertility, but also much slower growth rate. Steers which receive 2 1/2 ounces of bone meal under phosphorus-deficient conditions will have carcasses weighing approximately 750 pounds at the age of four years, while those steers which were control animals and did not receive the 2 1/2 ounces of bone meal a day have carcasses weighing 350 pounds. Just adding bone meal to a phosphorus deficient ration makes all the difference.

The rainfall and temperature of any particular region determines the protein value and the crude fiber content of its pastures. In all those regions of Britain where the domestic breeds of livestock, such as the Hereford, Shorthorn, Sussex, and Aberdeen Angus have been evolved, we find that the average monthly rainfall is approximately 2 inches per month and that the atmospheric temperature varies from an average monthly temperature of approximately 40°F. during the winter months to approximately 60° to 65°F. during the hottest month of summer. In those areas with a temperate climate and a steady rainfall, we find that pasture growth is slow, that crude fiber is low, and that crude protein is high; those are the areas where we find really succulent pastures.

New Zealand is a country with an average monthly rainfall of approximately 2 1/2 to 3 inches per month and where the average monthly temperature very seldom exceeds 65°F. In that country we have some of the lushest, mainly artificial pastures in the world with a very high carrying capacity.

In most semi-arid countries the rainfall is seasonal. There are dry seasons with little or no rain and then short seasons with very heavy downpours during the rainy season. In a country like South Africa, the average annual rainfall in some of the

semi-arid regions is approximately 16 inches, of which approximately half falls from the beginning of December to the latter part of February. The average monthly temperature varies from approximately 60°F. to 80°F., with an average annual isotherm of 65° to 70°F. In those areas pastures grow very rapidly, hence are high in lignin content; that is, the crude fiber content is high and the protein value is low. In semi-arid regions livestock often suffer from nutritional deficiencies, especially energy and protein, for a fairly long period during the year.

Temperature is a most important factor which determines which type of animal can be maintained in a particular region. In areas where the atmospheric temperature is high and where the average annual isotherm, that is the average temperature for the whole year, is high, unadapted cattle will degenerate. Very few of the British breeds of livestock can thrive in areas where the average annual isotherm is above 65°F. If the average annual isotherm exceeds 70°F., the British breeds of livestock will suffer from tropical degeneration. Tropical degeneration is not only characterized by stunted growth, but also causes a very marked reduction in fertility. Animals which are not tropically adapted, that is animals which cannot withstand high temperatures, become hyperthermic and often show a rise in body temperature to as high as 104°F. and sometimes even as high as 106°F. on a hot day. Young animals from the age of

she produced a smooth coated calf. At the age of seven years, the woolly coated steer weighed 870 pounds and the sleek coated one weighed 1360 pounds. Hybrid vigor had no value whatsoever in the animal that was not adapted.

Several of the woolly coated Africander bull's purebred female progeny were mated to sleek coated Shorthorn bulls. The Africander cows which were the progeny of the woolly coated Africander bull by sleek coated Africander cows produced some smooth and some woolly coated calves. When the Africander cows which were heterozygous with regard to coat cover were bred to smooth coated Shorthorn bulls, they produced smooth- and woolly-coated calves. The calves that were born sleek coated could overcome the hazards of the subtropics; they did not show a rise in body temperature or hyperthermy, not even when they were very young. Those that were born woolly coated could not overcome the hazards of high temperatures and at the age of 8 years the steers that were born sleek coated weighed on an average of 1,680 pounds, while those that were born woolly coated weighed only 800 pounds.

That hair coat and hair cover play a tremendous role in the adaptability phenomena of cattle in the tropics and subtropics cannot be doubted. The animal with a sleek, thick hide with high vascularity will bleed profusely if the hide is punctured but injuries will heal rapidly; such animals are well adapted to high atmospheric temperatures. Wounds inflicted in the animal with a thick, movable, vascular hide heal within a week to ten days, while the wounds inflicted in the animal with a woolly, thin coat with low vascularity often take three weeks and longer to heal.

Another interesting phenomenon which was observed in these animals of low heat tolerance is that miniature calves could be produced when these low heat-tolerant cows were mated in early spring and were pregnant throughout summer. Calves as small as 19 to 40 pounds were produced out of these low heat-tolerant cows which were pregnant during the summer months. An interesting phenomenon in this respect is that in every instance the bull calf weighed lighter than the heifer calf. This is the result of the fact that the male fetus has a higher metabolic rate than the female fetus and hence, the cow which suffers as a result of hyperthermy suffers appreciably more when pregnant with a male calf. Hence, the difference in weight between the male and female calf. (In normal calves, the male calf is always heavier

ı the female calf.) These calves are often so small that they scarcely reach the udder of the cow. That the phenomenon of ıiature calves is caused by the lack of adaptability of the :her cannot be doubted. Africander cows mated to Hereford ls produced normal calves, that is, cows which were heat tol- nt when mated to Hereford bulls produced heavy calves at th while the reciprocal cross, namely Hereford cows with a , heat tolerance coefficient, when mated to Africander bulls ›duced miniature calves. The difference in weight between the o reciprocal crosses was approximately 40 pounds as com- red to 75 pounds. Some of these calves were so small that ey were the size of an ordinary Doberman pinscher dog.

In Australia the phenomenon of very small miniature lambs areas such as Queensland was encountered and the cause was ıt known. In 1949, when these results on the cattle were dis- ıssed in Australia, it was mentioned that the miniature lambs ight be caused by ewes being pregnant during mid-summer, ıat some ewes were more heat tolerant than others, and that ıose ewes which lack heat tolerance would produce the small ımbs. Hence, Dr. George Moule and Neal Yeates mated a num- er of ewes and placed half the number of pregnant ewes in cold ooms and the other half in hot rooms. Those that were placed ı an environment of 85°F. produced lambs weighing 4 pounds. 'hose which were placed in an environment with an average emperature of 65°F. produced lambs which weighed an aver- ıge of 8 pounds.

Light is a most important environmental factor greatly in- luencing the metabolism and behavior of animals. Light is the nost constant of the natural phenomena in nature. Temperature ›n a specific date in different years might vary markedly, but the hours of light on the same date of one year as compared to that of another year differ very little. As a matter of fact, the daylight length on one date of one year is the same as that of another year. Hence, light has a very marked influence on the metabolic process in the animal. It influences sexual activity, hair shedding, and metabolism. Animals which are light colored or white become light or photosensitive when they eat certain types of plants. If a cow eats goat's thorn (*Tribulis terestes*), the whole white area of such an animal's body will slough off and become one festering sore.

In the case of other animals such as horses and mules, if they

ılants which make them photosensitive such as goat's thorn, will develop all sorts of photosensitivity symptoms. In the of a white mule which consumed *Tribulis terestes*, its whole looked as if it were corrugated. The unpigmented areas swollen while the pigmented areas were normal. Animals h consume plants like lantana which cause severe photo-tivity suffer most severely. If a cow or horse eats lantana, comes photosensitive and, if exposed to light, will certainly A Friesland cow which consumed lantana exhibited the se-st photosensitivity symptoms; all the white areas of her were badly *inflamed; it became one large sore with com-* loss of the white hair. The animal was placed in a dark e and it soon recovered. Mucous membranes also become 'ely inflamed. Horses which consume plants which make photosensitive, probably lantana, develop vast sores on bodies. This is known by the term of sandburn in Texas. arly as 1909, the veterinarians in the United States have to solve this problem and as yet, they haven't the answer . It would be advisable in every instance to put animals h suffer so severely from sandburn in a dark stable.

diation is another environmental factor which has a very :ed influence on the animal. *Animals which have no pigment*

operation, but this is not very successful. The incidence of cancer in the eyes of animals which have pigmented eyelids is negligible. By selective breeding (breeding Herefords with pigment around the eyes) the amount of pigmentation in the offspring can be increased and such eyes will never suffer from eye cancer.

A survey made on Hereford cattle in South Africa showed that in the young animals, the proportion of animals with pigment around the eye is relatively low. In the older age group, that is in the group of six years and older, it was found that the proportion of animals with pigment around the eyes was much greater. In other words, the mortality rate of the animals without pigment around the eye is appreciably higher up to the age of six years than it is in those that have pigment around the eyes.

In an experiment at Oak Ridge, Tennessee, irradiated pigs lose their hair and have sores on the side which is irradiated.

Animals can overcome the hazards of ultraviolet radiation if they have pigmented hides. A white color in the animal is a real hazard especially if the hide has no pigment in it. Animals which are tropically adapted like some of the Brahman breeds or white Africander or white 'N Guni cattle will have pigment in the hide. If the hair is shaved off, the hide will appear to be brown or even black. These animals with dark hides can overcome the hazards of ultraviolet radiation, and they usually have a profuse secretion of zebum in the hide which is spread over the hair. The zebum acts as an ultraviolet filter. Animals without pigment suffer severely, and all breeds of livestock which lack pigment in the hide suffer from a condition which is known as "white heifer" disease, in other words they are sterile.

In a group of 'N Guni cattle, those which have pigment in the hide when branded show a dark number, while those which are devoid of pigment in the hide show a white number. The white heifers suffer severely from ultraviolet impingement and are usually sterile.

The influence of coat color and cover on the adaptability of animals is not well understood. It is very essential that more work be done on determining how color influences the adaptability of the animal to higher incidence of infrared radiation, ultraviolet radiation, and total solar radiation. It is essential to determine how these various colors react under the different nutritional conditions. At the Messina Research Station in the Northern Transvaal of South Africa, I bred cattle which were

black, red, ash grey or agouti, golden yellow, and white. It is my intention to put these animals under artificial ultraviolet radiation and infrared radiation, test them out in the photo period room and under natural conditions, and determine how they react.

High altitude is a real problem to most animals. In high altitudes cattle must have a higher hemoglobin index than at low altitudes. In the early work done by Duerst, a Swiss animal scientist, he proved that the high altitude cattle of Switzerland, the Brown Swiss and the Simmental, had a higher hemoglobin index than any of the other breeds of cattle in Europe. We must evaluate the adaptability phenomena of animals adapted to high altitudes to really understand the adaptability phenomena required by cattle at those altitudes. The llama which is an animal beautifully adapted to the high altitudes of the Andes Mountains has a red blood count which is more than twice that of the human being. The llama on an average has 14,000,000 red blood cells per cc; man has approximately 5,000,000. The affinity of llama blood to oxygen is also twice as high as that of the human being; hence, the llama is four times as efficient in utilizing the oxygen in the rarefied air at high altitudes than man. At high altitudes, we find various breeds of cattle which show certain adaptability phenomena. In Switzerland we find the Siementhaler and the Brown Swiss and, from a color point of view, the Brown Swiss with its dark pigmented hide is appreciably better adapted to the high altitudes than the Siementhaler. The Siementhaler's white areas become hyperkeratinized and those animals often suffer. In high altitude, semi-arid regions like that found in Southwest Africa, the white areas of the Siementhaler are a real hazard.

ment. The subtropics also has a high ultraviolet radiation impingement. It has low oxygen tension as a result of high temperatures; and the only problem which the Brown Swiss animal has to overcome in the tropics is to radiate energy, and that can be brought about by selecting Brown Swiss cattle which are sleek coated.

Another environmental factor which requires certain adaptability phenomena in the animal is wind. In the northern parts of Scotland and in the eastern seaboard of New Zealand, wind continuously blows, and the winds are not only cold, but also moist; hence, all the animals which are adapted to a moist, windy environment have a long outer protective coat and an inner heat retaining coat. But the most beautiful adaptability phenomenon in these animals which are adapted to cold, moist winds is that their hair is of two types, the inner heat retaining coat and outer protective coat, and these coats are electrically oppositely charged. The inner heat retaining coat is positively charged and the outer protective coat is negatively charged. If wind blows over these animals, the charge becomes stronger and the hair packs closer and the animal becomes not only waterproof, but also cold-proof, and the insulating coat is really functioning efficiently. Any breeder can grow hair on cattle if he blows atomized moisture over them. That is why so many Hereford breeders, when they want curly hair on their cattle, blow moisture over these cattle with a strong fan.

Pigs which are constantly exposed to severe cold and wind develop long, woolly hair. In the mast forests of Yugoslavia, Mangalizza pigs exist on nuts of various types and are at all times exposed to the climate; these pigs are woolly coated, almost as woolly as a sheep. In 1770, Captain Cook on his exploratory travels in the region of the Antarctic dropped a number of pigs, of the type maintained in England at that time, on the Campbell and Cook Islands which are in the Arctic Zone south of New Zealand. In 1943, a few research workers of the Ruakura Research Station in New Zealand who were stationed on the islands to do radar work during World War II, encountered pigs and they found that those pigs which were on the Campbell and Cook Islands were long haired and had two types of hair, an inner heat retaining coat and an outer protective coat. Only those pigs which had the genetic potential to develop an outer protective coat and an inner heat retaining coat could survive. After

almost 200 years, there were large numbers of these pigs which were well adapted to the Arctic regions.

An environmental factor which has received very little attention in the literature on ecology is soil pH. Not even in a really comprehensive article by Wright in "Hammond's Physiology of Domestic Animals" is soil pH discussed. In any area where the soil pH is high, nitrification of the bacteria in the roots of leguminous plants can take place, and if nitrogen can become available to pastures, the pastures are higher in protein value. Leguminous trees such as some of the Acacia species are indicative of a high soil pH. A soil pH of approximately 6.5 will produce pastures relatively high in protein; the calcium in such pastures is usually readily available to the cattle and hence, they have good skeletal development.

In areas where the plant growth is of a type indicative of low soil pH, as in the case of *Combretum apiculatum*, animals maintained there have a poorer skeletal development than in regions where the soil pH is high. At the Mara Research Station, the one pasture with a high pH, that is the pasture in which the predominant tree is *Acacia tortulis*, we could grow big cattle; while in a pasture not three miles away we had *combretum apiculatum* grazing with a soil pH which is low, and the animals kept in those pastures were appreciably smaller.

Steers indicative of the average of the two groups of animals kept in the Acacia pastures and the Combretum pastures differed 300 pounds in weight at three and one-half years. The steers in the Acacia pastures averaged 1,250 pounds when those in the Combretum pastures weighed only 950 pounds. Soil pH is a factor which should be taken into serious consideration in the ecological livestock work in Texas. For example, so many farmers or cattlemen do not fully appreciate why cattle from East Texas grow out so much bigger in West Texas. Most pastures in

pastures of the coastal regions and to the higher rainfall, lower pH areas of Swaziland. The mature cows of this breed on an average weigh approximately 750 pounds. Africander cows which were maintained on pastures with a soil pH of approximately 6.2, on an average weighed 300 pounds more than Africander cows which were maintained on pastures with a soil pH of 5.4. The problem of varying soil pH values had a marked influence on the skeletal development of cattle in Holland and it was known as long as a hundred years ago. It was known in Holland for a very long time that cattle which were maintained and kept in areas where forests and sandy soil with low pH was encountered had small body conformation and were light boned. Those animals which were kept in areas where the soil was what they called "heavy," that is soil with a high pH, were large framed and heavy cattle.

Animals which are adapted to low soil pH and high humidity are most often shade lovers. The 'N Guni cattle in Swaziland for instance, where the humidity is high and the soil pH is low, are real shade-lovers because it is a hazard to the animal to radiate energy in a humid climate if they are not in the shade. Hence, those animals are really forest dwellers. Coastal animals are usually light colored. Animals in coastal and humid areas very often are very light colored, ash grey or almost white and must have pigmented hides.

A hazard to many animals in their natural environment are insects, ticks, mosquitoes and flies. Tick borne diseases are a real hazard to most areas on the African Continent, and in research work done by Baque in Cuba many years ago it was stated that ticks remove as much as 96 kilograms of blood from one animal per annum. We can overcome these hazards of ticks by both proper management and by breeding. Animals can be bred to repel ticks. Those animals which have thick and movable hides, well developed panniculus muscles and which have a sensitive pilimotor nervous system will move their hides very rapidly upon the slightest irritation and hence, will repel ticks more efficiently than those animals which have woolly hair and thin hides. The animal that can repel ticks has well developed panniculus muscles, while those that cannot have poor panniculus muscle development. The hide of the animal in those regions where tick borne diseases are a hazard is one of the most efficient immunizing organs one can think of. Those animals which have

thick hides become immune much more readily and succumb much less to tick borne diseases than those with thin hides and woolly hair.

The conquering of the screwworm hazard in Texas and other Southern States of America will completely change our approach to livestock production. As a result of the eradication of the screwworm fly, the problem of screwworms has almost become a thing of the past. This has made possible the increase in the deer population in many of our natural grazing areas in Texas and other Southern States and has caused us to realize that the carrying capacity of these pastures as far as livestock is concerned has changed. Apart from this, because of screwworm eradication, we can now probably produce calves in other seasons of the year than we did in the past. It is my considered opinion that as a result of conquering this plague, the livestock industry will have to do new research work on cattle and pasture management, breeding seasons of cattle, and on the concept of carrying capacity.

Animals vary in their ability to overcome the nuisance of flies and other insects. If we go in a pasture we find that certain cows or horses are full of flies and other biting insects, while others are free from them. It is possible to breed cattle which will repel ticks, flies, and mosquitos. The animal with a straight hair, with a sensitive pilimotor nervous system and well developed panniculus muscles, and which gives off zebum, will repel more insects than the animal which has a dull, dry coat and which does not have a sensitive pilimotor nervous control. The animal which becomes stary coated when rain looks imminent is an animal which repels ticks and flies; the erector pili muscles make the hair stand up and this in all probability stimulates

tures is largely one of internal parasites. Animals susceptible to external parasites are also more susceptible to internal parasites. The animal which is less adapted and hence has a lower nutritional status in a particular environment usually has a high incidence of external parasites and is often infested with internal parasites of one kind or another.

Disease is a factor which plays a tremendous role in the production of livestock, and lack of adaptability causes animals to be more susceptible to various diseases. In the case of a disease such as ricketsiosis (heartwater) which is a tick borne disease, certain breeds of cattle are much more susceptible than others, and those animals which are low heat tolerant usually more readily succumb to this disease than well adapted heat tolerant cattle. Sheep which suffer from this disease, if they survive, lose their whole fleece.

In some parts of the world, nutritional conditions cause certain endemic diseases or disease conditions; for instance, subterranean clover in Australia causes bearing down disease in sheep, which is nothing else but prolapse of the uterus. The subterranean clover is so high in estrogenic hormone that these sheep suffer from prolapse of the uterus. Any type of disease which causes the animal to have a high temperature for a few days results in permanent damage to the pituitary and shedding of the hair which will never grow out normally. These animals are always subfertile.

The most sensitive index of adaptability in all animals is their ability to reproduce regularly. Endocrine balance is the most sensitive barometer of the animal's ability to be adapted to a particular climate. The scrotum of animals is a most efficient thermo-regulatory mechanism, and in some breeds of goats the testicles are carried in two separate scrotums so that thermoregulation is more efficient. The testes are in a scrotum with an appreciably larger surface area than it would have been if the testicles were in one scrotum. The scrotum of adaptable cattle has a much thicker hide than those of cattle which are not adapted to the subtropics. And those breeds which are adapted to the tropics have scrotums which can pucker on cold days; furthermore, the spermatic vein in the subtropically and tropically adapted breeds of livestock is much more tortuous than in those of cattle from the temperate zones. When injected with radio opaque substance such as Chlor-bismuth, the volume of radio

and the homestead in Holland are more often than not under one roof. The animals in wintertime are the air-conditioning mechanism of the Dutch homestead; the heat given off by the stabled animals keeps the house warm in winter. The stable and the living room are separated by only one single door. Above the animals in the stable is the barn which contains the hay. As in Switzerland every cow's tail is tied to the roof to prevent it from getting dirty. As a result of the close relationship between man and his cattle, the animals are under continuous supervision by the owner, and many of these cattlemen told me that their cattle have a soothing and calming effect upon them. The tranquility of the cows chewing their cuds in a comfortably warm stable has a favorable psychological effect on the husbandmen; if for any reason they are worried the first thing they will do is to go into the stable where these tranquil cattle are.

During the winter the Friesland cattle are kept under an artificial climate created by themselves as a result of radiating energy in the stables. When these animals are out on the pastures in Holland, the stables are taken to the cows, not the cows to the stable, to be milked. They have portable milking machines and the cattle are milked on the pastures.

In France where they have the Charolais cattle, the main object of these animals is to produce beef with very little fat on it; hence they have produced very large cattle and such cattle can only be produced on pastures which have a high nutritional value. The pastures in the regions of France, namely Nievre and Vichy, where the largest herds of Charolais cattle are found, are very lush and have many herds in them. The animals during summertime show a dark discoloring around the pinbones as a result of the scouring on the lush pastures. The Charolais cattle are very lethargic and these cows and calves will not move even if one goes up to them. They are also animals which have very little resistance against tropical and subtropical diseases when taken out of their natural habitat. The white color of those animals in some instances is a real hazard.

In a country like New Zealand where no concentrate feeding takes place and all the production of milk is off green pastures, selection has taken place to select those Jersey cattle which have tremendous stomach capacity to enable them to produce enough milk. Only those animals which can consume enough green pasture to produce enough energy and nutriments on a completely

dry matter basis are continually kept and maintained in the herds. Ninety per cent of the dairy cattle in New Zealand are Jerseys, and one is struck by the tremendous stomach capacity of these cattle. As a result of the lush pastures and as a result of the fact that practically no concentrates are fed to cows in New Zealand, most cows calve down in early spring, the incidence of twinning in Jersey cows in New Zealand is appreciably higher than in other parts of the world. At the Ruakura Research Station in New Zealand they had at one time no fewer than 222 pairs of identical twins in experimental work.

The standard of livestock production in a country depends largely on the cultural and religious background of the people. In those backward countries of Africa, India, and other parts of the world where the people are ignorant, superstitious, and prejudiced, the type of cattle are very poor. In Ovamboland, the cattle are kept overnight in corrals and the cows are milked by women in wooden pails. The wooden pail is cut out of wood and is never washed.

Animals in a natural habitat will exhibit certain adaptability phenomena. In thickly forested areas, we want black cattle because black cattle function better in an environment where the light is dull, the incidence of infrared radiation is low, and the ultraviolet radiation is fairly high. In areas of dense forest like parts of Mozambique, Swaziland or Angola, we find predominantly black cattle. Beyond the forested areas, in the open savannah country, the color of the animals changes to a grey, light fawn, or yellowish white. In densely forested areas, the breeding of black cattle is advocated.

small sample of hair from the animal's coat with a pair of small scissors, spit on it, rub it intensely and if the small sample of hair felts into a tight mass, the animal will never become sleek coated in a subtropical environment. A sample of hair of those animals which have smooth, straight hair which is medullated will not felt when moistened and rubbed. The hair of the woolly coated animal is of two types, namely, an inner heat retaining coat, the hair of which is not medullated, and an outer protective coat which has medullated hair; there are primary and secondary hair follicles in the hide. The smooth coated animal has medullated hair only, a hair comes out of each primary hair follicle and in most instances, there is a sebaceous gland attached to each hair follicle, hence the secretion of zebum in the smooth coated animal is appreciably higher than that in the woolly coated animal.

The complete coat cover of animals of the British breeds has been closely clipped and put through a felting machine. The hair of the woolly coated animals felted into a tight mass which required a pull of 26 pounds to pull it apart. In the case of the sleek coated animals, a pull of 4 pounds will separate any sample of semi-felted hair. Animals which have hair that does not possess felting properties are those that are tropically adapted.

The variation in the hair coat of calves within the British breeds, namely Hereford, Shorthorn, Sussex and Angus, is such that selection within the breed can be made to produce a more heat tolerant animal. There are more desirable variants in the Sussex and Hereford than in the Shorthorn breed of cattle. In the Herefords, further selection should take place to get pigmentation around the eyes. Although we can without great difficulty produce British breeds which are heat tolerant, it is very often much more difficult to get them immune to endemic diseases of the subtropics. In our research work it was possible to change the mortality rate of the British breeds from approximately 30 per cent to 10 per cent by breeding them to be tropically adapted. One reason why animals which are crossbreeds between *Bos indicus* bulls and Hereford cows are not as good as the animals which are produced by the Hereford bulls and the *Bos indicus* cows is that the *Bos indicus* cows possess much greater natural immunity against the endemic diseases of the subtropics and tropics. The calves suckling *Bos indicus* mothers in all probability obtain a greater spectrum of immune bodies through the

colostrum of the highly immune cow. In work where we switched calves from the Hereford mothers to the *Bos indicus* mothers and vice versa, the mortality rate of those calves which suckled the *Bos indicus* cows was lower than that of those that suckled the Hereford cows. This is a field of research work which should be carried out on a large scale in the Southern States of America.

Out of a tropical degenerate Hereford herd, it was possible to breed by strict selection for adaptability to the subtropics a herd of very well adapted Herefords. Selection was based on sleek coatedness, thick hidedness and pigmentation around the eyes. At the Mara Research Station in Northern Transvaal, a Hereford herd which was bred for tropical adaptation was established and in a period of approximately 15 years, it was possible to breed a completely adapted Hereford herd that had all the adaptability phenomena required for tropical adaptation. The only factor which could not be overcome was the susceptibility of these animals to tick borne diseases although the incidence was reduced. *The Hereford bulls selected in this program were all thick hided,* had pigment around the eyes, and the coloration of the hair on the neck, upper flank, lower rib regions and lower thighs was appreciably darker than the other hair.

In a survey made on the Hereford cattle in three ecological regions of South Africa, it was found that the Hereford cattle which had sleek hair in the subtropics were 200 pounds heavier at maturity than those that were woolly coated. In the region of the Mara Research Station the average mature weight of woolly coated Hereford cows was 990 pounds; medium coated animals weighed 1,090 pounds; while those that were sleek coated weighed 1,187 pounds. In a temperate region the difference was 1,030 pounds for woolly coated cattle, 1,044 for medium coated cattle, and 1,071 for sleek coated ones, a difference of only 41 pounds between the sleek coated and woolly coated cattle in the temperate region. It became very clear from this survey that adaptability phenomena such as a smooth hair coat is of much greater importance in a subtropical region than it is in a temperate region.

All animals can overcome cold if they are well fed. The major livestock problem in all tropical and subtropical regions where the average annual isotherm is above 65 degrees is tropical degeneration. And when the adaptability work at the Mara and Messina Research Stations was started in 1937, those areas had

thousands of cattle of the British breeds, Shorthorn, Hereford, Angus and Sussex which were typical tropical degenerates. But after having done careful research work on the factors which bring about adaptability in the subtropics, it was possible by selection and breeding and crossbreeding work to replace these animals by adaptable types. At Mara Research Station by crossbreeding and inbreeding, a new breed of cattle has been evolved, namely, the "Bonsmara." The Bonsmara was bred on fairly similar lines as those adopted in the breeding of the Santa Gertrudis breed in America, however, we adopted a few different methods in our selection program. Very little was left to empirical standards; animals were tested for climatic adaptation by taking their body temperatures, respiration rates and pulse rates. And as a result of the data obtained in this research work, it was decided to breed cattle which are 5/8 Africander and 3/16 Hereford, and 3/16 Shorthorn. After obtaining 5/8 Africander-3/8 Hereford cattle, and 5/8 Africander-3/16 Shorthorn cattle, these two types were interbred to get the 5/8 Africander, 3/16 Hereford and 3/16 Shorthorn. It was found that if animals had more than half the blood of the British breeds, that they could not withstand the subtropical conditions. Herefords were brought into the picture because they are better grazers than the Shorthorn, are more heat tolerant, and have a more even fat distribution than the Shorthorn. The Shorthorns were brought in because they are faster maturing than the Hereford, they have better milk production, and they are a uniform red color. By crossing the 5/8 Africander-3/8 Shorthorn with the 5/8 Africander-3/8 Hereford it was possible to develop a completely red animal without any white on it. I am absolutely opposed to white on any animal in the tropics and subtropics.

Some of these Bonsmara cows were selected for longevity, fertility and functional efficiency, and in some instances we have cows that are seventeen years old now that have had 15 calves. The heavier ones weighed over 600 pounds at 8 months and the lightest weighed 450 at 8 months. Any animal which shows hereditary weakness or a *locus minoris resistentia,* that is a point of lower resistance, is culled. The bulls used in the selection and breeding work at the Mara Research Station to establish the Bonsmara breed have to be functionally efficient. They must be able to serve fifty or more cows in a two and a half months' breeding season. They are sexually active and highly

fertile.

In the subtropical, semi-arid regions of the Transvaal Bushveldt, those animals which degenerated will be replaced by Africander types and Bonsmara types which are tropically adapted. The livestock production policy in South Africa is based on the regionalization of breeds and types, that is, the climate is carefully mapped and the breeds of livestock which should be used or bred in a particular area are determined by the climatic conditions of a particular environment and the corresponding environment in which the breed had its origin.

It is absolutely certain that in our breeding programs we have to consider the altitude, the soil pH, the temperature, radiation, light, humidity and the interaction of all those factors on the natural vegetation and how the cattle will react to the total environment. Only those animals which can survive and breed regularly in those areas in which they are placed will be of economic importance.

17

J. C. BONSMA

Genes and Phenotype Interaction

The complete genetic complex of the animal is laid down at the moment of conception. What the future animal will be like is predetermined. The morphology as determined by the complete interaction between the heredity and environment is laid down at fertilization. How the external effector organs, the skeleton, size and muscling, fat deposits, hair color, and breed characteristics of the animal will develop is in the first instant determined by the genetic pathway number 1, shown in Figure 19. The endocrine glands and tissues are also genetically predetermined at conception, and how these endocrine glands are going to function is genetically determined through the pathway No. 2, shown in Figure 19. The endocrine function and the endocrine balance can modify the morphology of the animal to a certain extent. The animal which is in complete hormonal balance will have all the growth functions completed in an orderly fashion. If hormonal disturbances have taken place and the pituitary, for instance, has not stimulated the sex organs, the secretion of gonadotrophins will be delayed and hence, ossification of the long bones in either the bull or the cow will be delayed and skeletal size will increase. The complete morphology of the animal can be changed as a result of hormones stimulated through endocrine. The animal which produces too much somatotropin will have its morphology changed through pathway 3 (Figure 19), that is, the growth hormones will modify the size of the external effector organs. It will modify the muscling and fat deposits and it will modify the hair coat and color of the animal. The central nervous system and its functioning is genetically controlled by pathway

4. The central nervous system, especially through the hypothalamus, determines the efficiency of the thermo-regulatory mechanism of the animal. The animal which does not have adaptability will show a condition of hypertherma on hot days, will suffer pi-

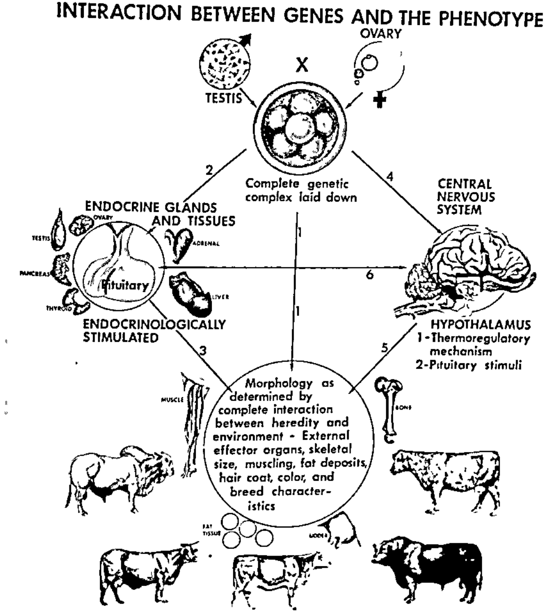


FIGURE 19. Six pathways involved in the interaction between genes and phenotype.

tuitary damage and hence, the whole morphology of the animal as a result of imbalanced hormonal stimula will be modified through pathway 5 (Figure 19). The central nervous system will have a direct influence on the endocrine glands, especially

the hypothalamus and the pituitary. The stimulation from the nervous system will cause endocrine function which feeds back through the central nervous system and will hence influence the reactions of the animal. Heifers which were placed with a vasectomized or teaser bull through pathway No. 6 (Figure 19) produced endocrine reactions as a result of the neuropsychological stimulus. The reactions which took place caused the heifer to become more sexually active and mature. As a result, the body conformation changed. It is therefore obvious that the ultimate morphology of the animal is controlled by the interaction of the complete genetic make-up and the total environment, the endocrines, and the nervous system.

18

J. BOND

Environment and Reproduction

A high calf crop percentage is the basic goal for the cow-calf man and any factor, or group of factors, that act to reduce reproductive efficiency are of great economic importance to him.

Calf crop per cent varies with region as is shown in Table 63. The national average is 86 per cent, varying from 70 to 90 among

TABLE 63.—NUMBER AND VALUE OF COWS AND CALVES, BY SECTIONS, 1963 AND 1962 CALF CROP*

SECTION	NUMBER IN THOUSANDS†	DOLLARS IN THOUSANDS‡	1962 CALF CROP§
North Atlantic	170	977,420	85
North Central	9,760	6,994,001	90
South Atlantic‖	2,453	858,796	79
South Central‡	11,024	3,063,134	84
Western	6,476	2,815,548	88
Alaska	1.6	2,020	80
Hawaii	75	34,992	70
U. S.	29,960	14,745,911	86

*U.S.D.A. Agricultural Stastics, 1963.
†All cows and heifers 2 years old and over, number on farms.
‡Total farm value.
§Not strictly a calving rate. Figures represent calves born expressed as percentage of the January 1 inventory of cows and heifers 2 years old and over and not number of all cows and heifers giving birth to calves during the year.
‖South Atlantic includes: Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida.
‡South Central includes: Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas.

regions. These percentages can vary within regions from as low as 30 to 40 under unfavorable conditions to 94 under good conditions and in well-managed beef herds. This means that some ranchers only wean 30 calves per 100 cows. The lowest rates are in the South Atlantic, South Central, and Alaska where there are extremes in climatic environment.

FIGURE 20. Calf showing a typical winter-type coat after 5 months of natural decreasing light. Courtesy of Professor N. T. M. Yeates, The University of New England, Armidale, N. S. W.

The effects of climatic environment on reproductive efficiency are complex. Climate is composed of a number of variables: temperature, light, humidity, air movement, radiation, rainfall, and altitude. Temperature is recognized as the most critical of these variables in livestock production. Extremes in these variables cause stress in the breeding animal and impair reproductive performance.

These climatic variables have an effect on soil, nutrition, disease, and parasites. These factors and their effects on calf crop are covered in this book.

It is known that these variables work together in producing the total effect of the natural condition of climate. The great majority of studies or observations have been made in the field where the variables are uncontrollable. Because of this situation,

there have been conflicting reports which were probably caused by the interaction of variables.

In general, cattle located in areas having high summer temperatures have their lowest reproductive efficiency during these months. In areas further north, where there are no consistently high summer temperatures, the poorest breeding efficiency is in the winter months. Reasons for differences in fertility in these areas could be length of daylight, temperature, or nutrition, or a combination of all. With this in mind, I will give a general review of the climatic environmental effects on reproduction.

Although cattle are bred during all times of the year, there are peaks of fertility during certain months of the year in different areas of the world. It has been observed that fertility is lowest in the winter months in Canada, northern United States, and parts of Europe. The short daylight hours have been blamed for this low level of fertility. A study has shown that semen quality gradually improved with increasing daylight until it reached a high in the long days of summer and fall. However, bulls under four years were higher in the winter and declined during the summer indicating that younger bulls were more affected by other factors such as temperature and possibly nutrition (Mercier and Salisbury, 1947). Louisiana workers (Roussel *et al.*, 1964) were able to improve semen quality during the hot and humid summer by lengthening daylight by using incandescent light. Conception rate in cows was highest during the longest days in Canada (Mercier and Salisbury, 1947). In Alaska, herds of cattle that received 14 hours of light per day had an average conception rate of 53.6 per cent as compared to 46.8 per cent for a group under natural conditions—having only 5 hours of light (Sweetman, 1950).

In a controlled experiment, length of the estrual cycle was normal in cows subjected to constant light and blindfolds, although blindfolded cows did have a shorter estrus period and

of estrus. Duration of estrus is shorter when environmental temperatures are high, which increases the possibility of missing estrus if a bull is not running with the herd. This can also be true in extremely cold weather.

Controlled experiments (Gangwar, 1964) showed that the length of the estrous cycle was lengthened but the duration of

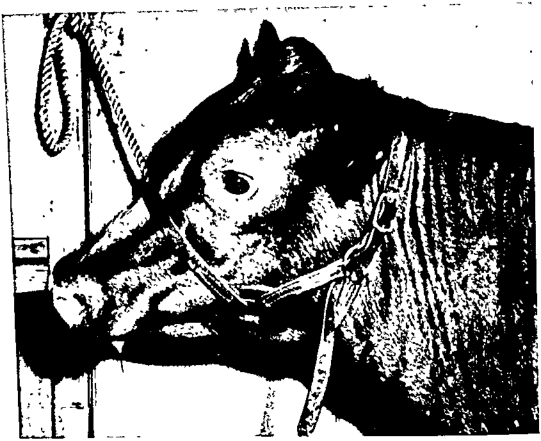


FIGURE 23. Heifer with summer coat showing no distress after a 3-hour exposure to 105° F. Courtesy of Professor N. T. M. Yeates, The University of New England, Armidale, N. S. W.

estrus was shortened under hot climatic conditions. He also found that the intensity and manifestations of estrus were decreased in the high temperature conditions. As in the U.S.D.A. experiments, the heifers did adapt to the hot conditions under adequate nutritional and management practices.

Puberty was delayed in Shorthorn and Brahman heifers raised at 80°F. when compared to heifer calves reared at 50°F. or in an open shed. Santa Gertrudis calves were not greatly affected (Dale *et al.*, 1959).

Pregnancy raised the susceptibility to stress conditions. High

abortion rates have been observed during the summer months. In a controlled experiment (Ragsdale *et al.*, 1948), two cows aborted 4½ and 6-month fetuses two days following a 27-hour exposure to 100° F.

In South Africa (Bonsma, 1955), miniature calves with birth weights of 22 to 30 pounds have been born to European beef cows

FIGURE 24. Heifer in winter coat showing heat stress after 3-hour exposure to 105° F. Courtesy of Professor N. T. M. Yeates, The University of New England, Armidale, N. S. W.

tures after the exposure of bulls to extremely high air temperature and requires a considerable time to return to normal. This condition leads to temporary sterility. Young bulls are affected most (Casady *et al.*, 1953). Sex drive is generally less in times of temperature stress either high or low.

Cattle can stand high temperatures during the daylight hours if they are able to cool off during the night. A constant high temperature will be extremely stressful and may prove fatal. The long term effect of constant moderately high environmental temperature is "tropical degeneration" of the European beef cattle, as observed by Professor Bonsma.

As weather gets colder, more nutrients are needed for the maintenance of body temperature. If inadequate nutrients are unavailable, the beef animal must draw on its body reserves for heat. If the animal goes down in condition, it could indirectly affect mating and parturition. Limited feed to the cow may also affect fetal development and lactation. The metabolism of the fetus helps protect the cow in cold weather. Calves are extremely sensitive to cold, as the temperature regulating system in the newborn calf is poorly developed, and there is the danger of death when they are exposed to harsh environmental conditions.

The calf must seek warmth and must nurse to keep up the heat balance in its body. If the calf is weak and its temperature falls fast after birth, it is less able and willing to nurse.

Wetness from *amniotic* fluid, rain or snow is a further hazard in cold weather especially when there is a wind. Although the cow is better equipped to maintain her body temperature against a cold than a hot climate, unusually severe weather occasionally proves calamitous. A classic example is the winter of 1886 when the western cattlemen suffered terrible losses.

Disaster struck the western ranchers again in December, 1964. A blizzard hit the Dakotas on December 16 with winds up to 50 miles per hour and temperature dropping to 36° below zero which lasted 48 hours (Henderson, 1965). Losses in some areas were as high as 10 per cent. Udder, teats, and ends of scrotums were frozen and fell off. Bulls had testes frozen. Adverse carryover effects on reproductive ability are possible in cattle not injured as greatly. Observations indicated that old cows and 2-year-old heifers, that had had a calf the spring of 1964, suffered the most. The fattest cows came through the storm the best.

Experience has shown that Canadian domestic breeds are subject to heavy death losses during periods of heavy snow cover and extreme cold unless feed is provided (Smoliak and Peters, 1955).

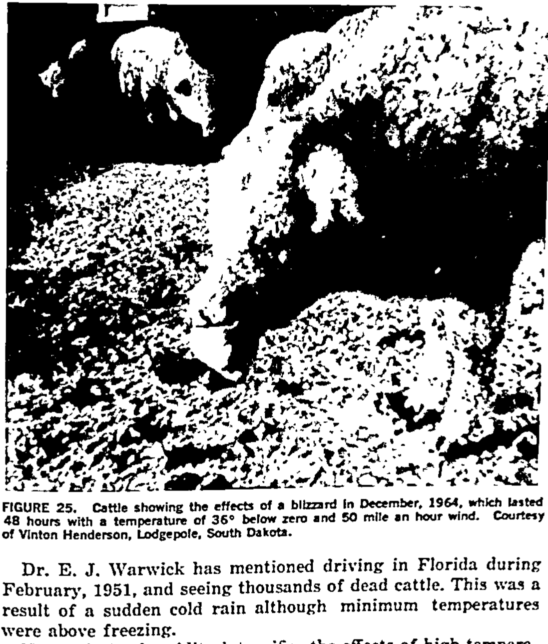


FIGURE 25. Cattle showing the effects of a blizzard in December, 1964, which lasted 48 hours with a temperature of 36° below zero and 50 mile an hour wind. Courtesy of Vinton Henderson, Lodgepole, South Dakota.

Dr. E. J. Warwick has mentioned driving in Florida during February, 1951, and seeing thousands of dead cattle. This was a result of a sudden cold rain although minimum temperatures were above freezing.

High relative humidity intensifies the effects of high temperature because it interferes with evaporative heat loss in beef animals, making heat regulation of the body more difficult. Animal comfort is related to the moisture in the air. Christie (1962) observes that in Southern Rhodesia the highest conception rate is at the time of highest temperature and lowest humidity. High

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FIGURE 25. Cattle showing the effects of a blizzard in December, 1964, which lasted 48 hours with a temperature of 36° below zero and 50 mile an hour wind. Courtesy of Vinton Henderson, Lodgepole, South Dakota.

humidity is conducive to pest and parasite infestations which cause animal distress.

Rainfall modifies the effects of temperature stress. It has a cooling effect which is an advantage in a hot-dry climate, but reduces the insulating ability of the hair coat, putting the animal at a disadvantage in cold weather. Soil and vegetation are affected by rainfall. Mineral deficiencies are likely in areas of high rainfall. Deficiencies in calcium, phosphorus, cobalt, and other minerals can result in lowered fertility. Lack of carotene in forages can result in a vitamin A deficiency. This can occur from a long dry season. It is extremely important to the improved pastures in Florida.

Solar radiation is a source of additional heat load on the beef animal's body, increasing the heat stress during high environmental temperatures. It can be absorbed directly or reflected from the surroundings. Bare or plowed ground reflects more radiation than pasture or crop land. The animal will stay under shade, reducing grazing time, during periods of high temperature and high solar radiation. High solar radiation is used as a source of heat by cattle to decrease cold stress. Solar radiation can cause irritation in the hides and eyes of cattle that lack pigmentation. Ultraviolet radiation can cause eye cancer.

Air movement is related to body heat loss. As wind velocity increases, there is a reduction in the effect of hair coat insulation. This effect is important in cooling cattle in hot-wet environments, reducing heat stress. It would increase cold stress during cold weather.

High mountain or brisket disease is a condition affecting cattle living at high altitudes (Alexander and Jensen, 1959). It has been observed in cattle in western United States and Peru, at elevations above 7,000 feet. This disease is a congestive failure of the right side of the heart, and it develops slowly. It affects all ages and sex groups with a higher incidence in calves less than one year of age. The affected animals are reluctant to move and often have diarrhea and a high and labored respiration rate, which can terminate in death. The incidence of this disease varies from 0.5 to 1.0 per cent of cattle ranging in the high mountains, with some herds as high as 5 to 10 per cent. It usually occurs during fall, winter, and spring months. The cattle may recover without treatment in a week up to 12 weeks when moved to lower altitudes. This disease, caused by environmental stress,

has an indirect effect on reproductive ability of breeding animals and calf crop percentage. Although studies with other animals and humans have shown that high altitude has adverse effects on testicular function and fertility, this has not been shown in cattle.

Exposure to atomic fallout is unique but interesting. A herd of 41 Hereford cows and 1 bull were accidentally exposed to fallout at Alamogordo, New Mexico, in July, 1945. The animals were given to the University of Tennessee for study. The four cows in calf at the time of the fallout dropped normal live calves. There were no differences in birth weight of calves. One cow (No. 52) lived 19 years and had 16 normal calves. This cow had received severe burns caused by the fallout.

An effect of high temperature stress is reduced voluntary feed intake. This occurs as heat stress increases. It is a method which cattle use to reduce body heat production but as a result the animal lowers its nutritional level. Tropical and subtropical forages are frequently of low nutritive value tending to have high moisture content, low protein content, low digestive carbohydrates, and high fiber content. Deficiencies in minerals and vitamin A also occur. During high and low temperature stress, grazing time is reduced. As the animal must maintain a certain nutritive level, especially during cold weather, for increased feed to produce heat, low reproductive performance may be wholly or in part due to inadequate nutrition.

Studies at two locations of different environmental climates at Beltsville, Md. and Jeanerette, La. by Wiltbank *et al.*, 1965, have shown that when heifers are fed adequately, reproductive performance is satisfactory. Dr. M. Koger has cited low nutritional levels as responsible for limited performance of cattle in Florida.

Indications are that climatic environmental stress acts directly on the reproductive physiology of the beef animal while indirect effects on reproductive efficiency due to inadequate nutrition are equally as important.

One of the quickest ways to reduce cost and increase profits is to increase calf crop percentage. Any practical way to reduce climatic stress will help to increase calf crop.

Based on information available, some of the ways are:

1. Use cattle best adapted to the area. An excellent book on this subject is *Crossbreeding Beef Cattle*, edited by T. J. Cunha, M. Koger and A. C. Warnick of the University of Florida.

2. Control disease and parasites.

3. Use shelters and shade in areas where necessary.

4. Provide fresh water. Water requirement of cattle increases when air temperatures are high and low. Cool water helps cool the beef animal during heat stress. Limited water allowances make heat stress more acute.

5. Provide sprays. This has been effective in the hot-dry Southwest.

6. Provide for adequate air movement. Fans have been effective where natural air movement is low.

7. Give beef females added attention at calving time.

8. Clip hair coats under extreme hot conditions.

9. Restrict exercise during periods of environmental stress.

10. Cull low fertility females.

11. Feed high-energy, low-fiber summer rations during periods of high environmental temperatures. The heat produced from the utilization of high fiber rations helps to protect the cattle against cold but contributes to heat stress.

12. Feed supplements to cattle on poor pastures when needed to maintain their condition.

13. Feed more good quality roughage during periods of severe winter weather.

14. Use improved pastures and good management.

SUMMARY

The effects of climatic environment on reproductive efficiency in beef cattle are complex. Climate is composed of a number of variables: light, humidity, solar radiation, air movement, temperature, etc. It is recognized that temperature is the most critical of these. Extremes in these variables cause stress in the breeding animal and impair reproduction.

Semen quality is adversely affected after exposure of bulls to high air temperature and the largest number of returns from breeding occur in the hot summer. In areas where the summer is cooler, lowest fertility usually occurs during the winter. This suggests that short daylight hours may cause reduction in fertility in northern areas.

Duration of estrus is shorter when environmental temperatures are high, increasing the possibility of missing estrus. Severe temperature stress will cause cessation of the estrual cycle.

Relative humidity intensifies the effects of high temperature while air movement is related to body heat loss. Solar radiation increases heat stress or decreases cold stress.

In addition to normal seasonal changes, the cattleman must be prepared for occasional unusually severe weather which strikes with little or no warning.

An indirect environmental stress is reduced voluntary feed intake. Tropical and subtropical forages are frequently of low nutritive value, and low reproductive performance due to inadequate nutrition is in this sense an environmental stress.

Anything which can be done to reduce climatic stress will help to increase calf crop percentage which is the basic goal for the beef cattle breeder.

19

J. C. BONSMA

Hormones in the Bovine

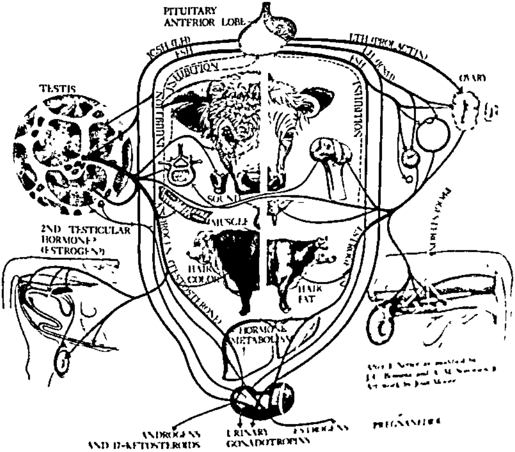
The bovine pituitary releases, in the case of the female, a gonadotropic hormone complex composed of follicle stimulating hormone (FSH); luteinizing hormone (LH) which is commonly designated in the male as the interstitial cell-stimulating hormone (ICSH); and luteotropic-like hormone (LTH). (Figures 26 and 27). The main function of the follicle stimulating hormone FSH in the female is to stimulate the growth of the ovarian follicles. It also acts synergistically with the LH hormone to promote maturation of the ova and estrogen secretion by the ovarian follicle. The bovine pituitary is lower in FSH relative to LH than in other domestic animals. LH hormone and the synergistic action of LF with FSH to stimulate estrogen production by the ovarian follicle have been mentioned. LH is also active in follicular maturation and rupture (ovulation) as well as in luteinization of granulosa and theca cells. It will also have an influence on the formation of the corpus luteum and very possibly initiates its production of progesterone.

Although ICSH may have some direct effect upon spermatogenesis in the male, its major action is stimulation of the interstitial cells of Leydig of the testis to produce androgens which are active in maturation of secondary spermatocytes and maintenance of spermatogenesis. The nature of LTH and its action as a luteotropic hormone in cattle remains obscure. It appears that prolactin, the LTH of the rat, is not the luteotropic principal in cattle. This evidence suggests that a luteotropic substance released at the same time as LH or perhaps LH itself is responsible for luteinization and initiation of progesterone production by

the corpus luteum. The possibility remains also that the act of ovulation itself may be sufficient stimulus to promote luteinization and formation of the functional corpus luteum.

The ovarian follicle under the influence of FSH and LH is the main source of estrogens. Although the corpus luteum and the adrenal gland are known to produce estrogens also, the signif-

HORMONES IN THE BOVINE



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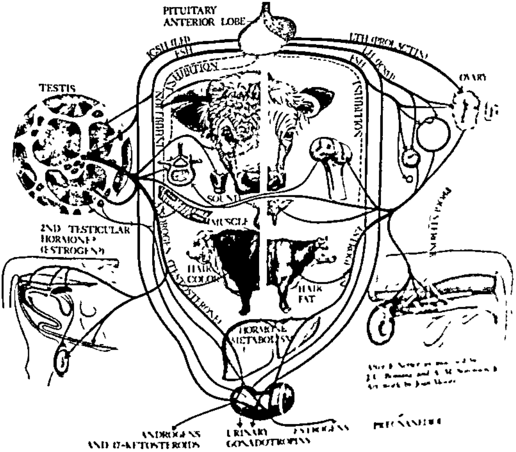

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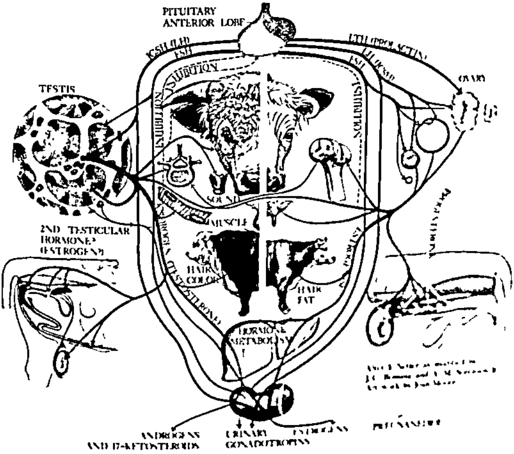

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The ovarian follicle under the influence of FSH and LH is the main source of estrogens. Although the corpus luteum and the adrenal gland are known to produce estrogens also, the signif-

HORMONES IN THE BOVINE

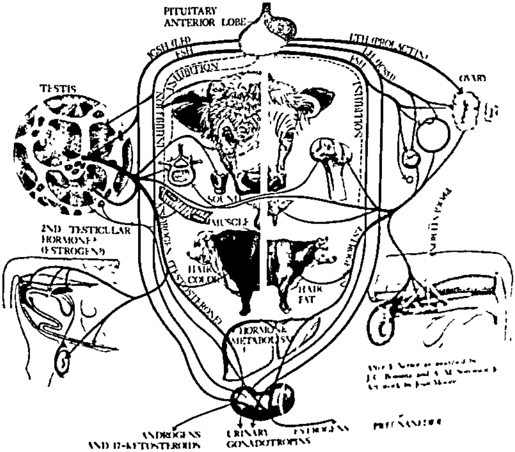

FIGURE 26. Hormones in the bovine.

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J. C. BONSMA

Hormones in the Bovine

The bovine pituitary releases, in the case of the female, a gonadotropic hormone complex composed of follicle stimulating hormone (FSH); luteinizing hormone (LH) which is commonly designated in the male as the interstitial cell-stimulating hormone (ICSH); and luteotropic-like hormone (LTH). (Figures 26 and 27). The main function of the follicle stimulating hormone FSH in the female is to stimulate the growth of the ovarian follicles. It also acts synergistically with the LH hormone to promote maturation of the ova and estrogen secretion by the ovarian follicle. The bovine pituitary is lower in FSH relative to LH than in other domestic animals. LH hormone and the synergistic action of LF with FSH to stimulate estrogen production by the ovarian follicle have been mentioned. LH is also active in follicular maturation and rupture (ovulation) as well as in luteinization of granulosa and theca cells. It will also have an influence on the formation of the corpus luteum and very possibly initiates its production of progesterone.

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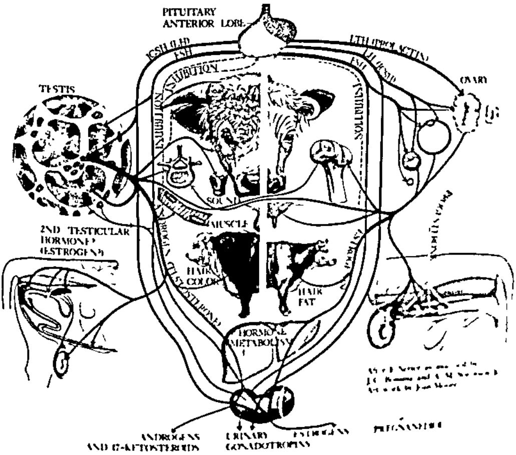

FIGURE 26. Hormones in the bovine.

19

J. C. BONSMA

Hormones in the Bovine

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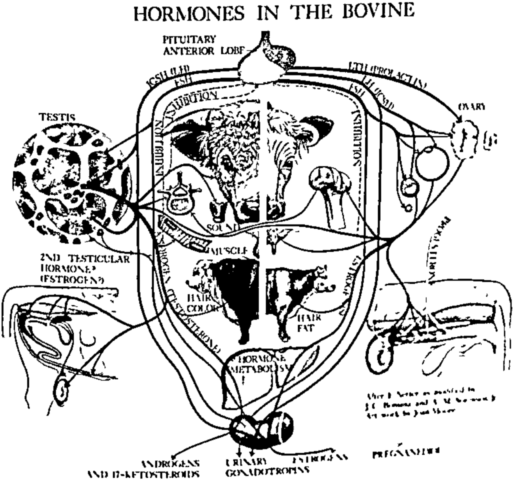


FIGURE 26 Hormones in the bovine.

trogen on the animal body cover a wide range of activities. Estrogen feedback to the pituitary, probably via the hypothalamus, suppresses FSH release. Also via the hypothalamus higher levels of estrogen are believed to cause release of LH. Under influence of estrogen the vascularity of the female reproductive tract is increased, the endometrial arterioles being more numerous and coiled. Uterine muscle cell size is increased and there is an accompanied increase in uterine motility during the estro-

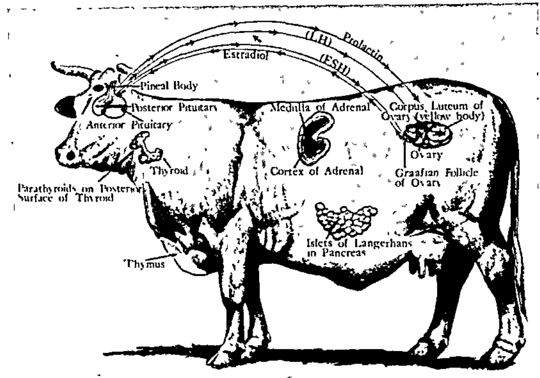


FIGURE 27. The endocrine glands in a cow.

gen phase of the cycle. Mucosal changes in the cow's reproductive tract are less prominent than in other animals, probably due to the overall lower hormone levels. Nevertheless, the thickening and cornification of vaginal epithelium, the increased activity of the mucus secreting cells of the cervix and the congestion and edema of stroma plus hypertrophy of uterine glands during pro-estrum and estrum can be attributed to estrogen increase.

The action of estrogen on mammary development is primarily upon tubular growth, but there is increasing evidence that estrogen may have a large effect on alveolar growth as well, especially in ruminants. Generally systemic effects of estrogens include increased rate of cell division thus promoting tissue

pulse to the brain that has a pathway to the central nervous system, causing certain behavorial patterns.) Pathway 5 (Figure 19) is the pathway from the central nervous system directly to the effector organs. This has a marked influence on the animal through the thermo-regulatory mechanism and through pituitary stimulus. The expression of the animal's genotype in its phenotype (i.e., its total morphology is the product of the interaction of the external environment such as nutrition, tempera-

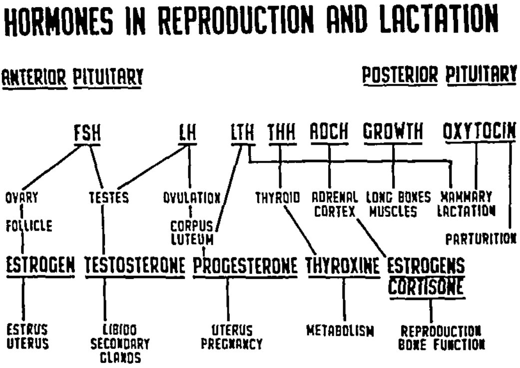


FIGURE 28. Interaction of hormones upon one another.

ture, etc., as well as the internal environment) is the result of the action of the endocrines on the gene complex laid down at fertilization. Figure 19 illustrates the various pathways.

Figure 28 is a diagram which implicates the interaction of the endocrines upon one another. (The function of each endocrine is indicated in bold print.) The pituitary secretes gonadotropin—gonadatropins are hormones which stimulate the sex glands—these hormones have a direct influence on the gonads, i.e., the testes or ovaries. The pituitary gonadotropin lutenizing hormone has a direct influence on the interstitial cells of the testes, which in turn produce testosterone, the male sex hormone. Testosterone has a marked influence on the male secondary sex characteristics of the bull. If there is a breakdown anywhere in the chain

reactions between hormones, this will be reflected in the morphology of the body conformation of the animal concerned. The same holds true for the female. Another pathway of a pituitary trophic hormone is through the corticotropin, and its effect on the adrenal cortex. This is reflected by hair growth, carbohydrate metabolism, and male and female secondary sex characteristics. The thyroid gland has a marked influence on the metabolism of the animal. If any one of the hormone functions is severely interrupted, this will be reflected in the external morphology (body conformation) of the animal.

Figure 27 is a diagrammatic drawing of a cow which indicates where the various endocrine glands are located and how these

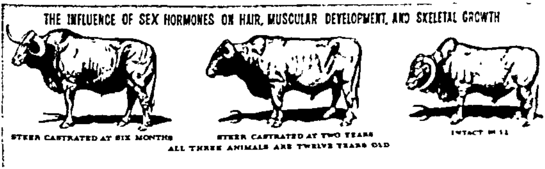


FIGURE 29. The effect of age of castration characteristics of the male.

on the masculinity of the head. In the human being it is the beard, a receding in the hairline, and baldness; in the bull, it is coarser hair on the head, neck and a special pattern of hair on the neck, upper shank region, lower midrib region, and lower thigh. It has a direct influence on the sound the animal makes, the way the animal bellows. When an animal bellows, a real experienced cattleman will tell you whether it is a bull, steer, or cow bellowing. The male sex hormones have a direct influence on muscle growth. All the data accumulated so far on feeding steer, bull, and heifer calves clearly illustrate this. The male calf's rib eye muscle is appreciably larger than that of the female or that of the steer. This phenomenon is controlled by hormone action. Since the male hormones cause an outward visual expression of masculinity, any imbalance or impairment of secretion of the hormones will cause the bull to lack the appearance of a normal male. The ossification of the epiphysis is dependent upon the secretion of estrogen in the case of the cow and testosterone in the case of the bull. The sex hormones have a direct bearing on the development of the sex organs such as the testes and also on whether the animal will have sex urge, or libido. The end products of the hormones are given off through the kidneys and I think we now have enough proof that the end products are also eliminated by the liver through the bile.

These sex hormones are steroids; steroids belong to the chemical compounds, fats. The steroids (fats) of the sex hormones are probably absorbed or diluted by the fat of the animal which has become overly fat. Such hormones have been found to be secreted in the bile of fat animals. The sex hormones are absorbed in the adipose tissue and are excreted through the liver. The male and female sex hormones have a direct bearing on total growth.

Figure 30 is a composite drawing of a left femur of a heifer that has reached puberty. The epiphysis, that is the epiphyseal cartilage line at which end the bone grows in length, ossifies when the animal reaches puberty and when sexual maturity has taken place. Figure 30 also shows the femur of a two-year-old heifer, where the epiphysis has just reached the stage of ossification, but has not ossified completely so it is separated at the epiphyseal line. The time of ossification depends on the hormone balance. The secretion of estrogen in the case of the female and testosterone in the case of the male causes the bone to

ossify and the overall growth of the animal is stopped because the bone growth has discontinued. If ossification is delayed, the animal continues to grow and becomes taller and taller, hence the objection to the very tall animal. An animal should be large lying down, but should not be large and long-legged and indicative of an animal with an imbalanced hormone control.

The ovarian hormones or female sex hormones have a direct bearing on the udder formation of the heifer. All the stages of

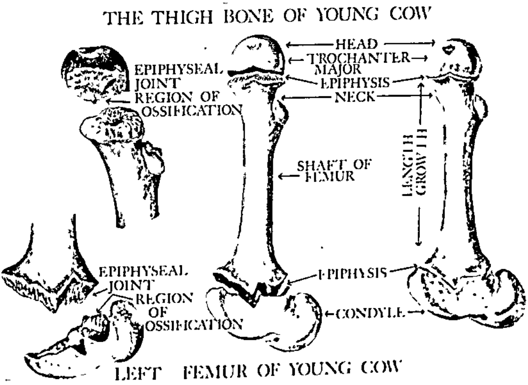


FIGURE 30. The left femur of a young cow.

development in the animal take place in a very orderly fashion. When the heifer reaches puberty, udder development takes place. That is the way by which we judge that the animal is functioning normally, she is cycling normally. In the case of the cow, the sex hormones also determine when the long bones are ossified. The relationships of the various bones to the body and toward one another furthermore influence the total expression of masculinity or femininity which in turn is an expression of gonadal function.

The pituitary gland which is situated on top of the palate below the brain secretes certain hormones which have a direct influence on the various organs of the body. It has a marked in-

fluence on the thyroid and hence, on the total metabolism of the animal. It also has a marked influence on the adrenal gland, especially the adrenal cortex. The adrenal cortex gives off a sex hormone, androgen, which stimulates the animal's sex activity —libido. The adrenal cortex produces the hormone which causes melanisation of the hair, that is the darkening and probably the thickening of the bull's hair so that the bull has a really masculine appearance. The pituitary secretes hormones which have a direct influence on the testes, on the ovaries, and on the growth of the long bones. The somatotropin is the hormone which stimulates total growth.

The basis of judging livestock for functional efficiency is illustrated by the work of Zawadowski. If a cock is castrated, its whole endocrine system is thrown out of balance and it becomes a capon, but if the ovary of a hen is grafted in the neck of the capon, it develops all the secondary sexual characteristics of a hen. If a hen is ovariectomized, it is a capon that looks like the capon produced by caponizing a cock, and if the testes of a cock are grafted in the neck of the ovariectomized hen-capon, an animal is produced with the secondary sexual characteristics of a cock. In other words, sex reversal can be experimentally produced as far as the secondary sexual characteristics are concerned.

The whole basis of the approach to livestock judging on a functional efficiency basis is based on this—if a bull is castrated, it is an ox. If the ox is treated with female sex hormones, the ox will resemble a cow; this was done experimentally for the McGregor Field Day that was held in Texas on March 4, 1965. These changes brought about experimentally in cattle often take place in animals under natural conditions.

The question arises, why have we not judged cattle on a functional efficiency basis earlier? One big reason is that every textbook on endocrinology mentions that the steer resembles a cow. That is not true—a steer resembles a steer. It is my considered opinion that the whole livestock judging system has been ruined by the ridiculous attitude of showmen who laid down the ideal breed standards based on the body conformation of the two-year-old ox for both the male and the female. If show animals are studied carefully, especially from a functional anatomy point of view, it is very obvious that the show bulls have less male sex characteristics. The Aberdeen Angus bull that was sold in Britain in 1963 for the highest price ever paid for a bull,

namely 60,000 pounds or $200,000 was completely sterile and one could clearly see that he was not masculine; his muscling was not clearly defined, and he had fine feminine hair over his body.

It is my considered opinion that the three illustrations of the twelve-year-old bull, the steer castrated at two years, and the third one castrated at eight months are really dramatic in illustrating how the male hormones or lack of them changes the body conformation (Figure 29).

A bull is a bull because his testes are intact and functioning. He has masculine hair on the sheath at the opening of the penis, is a really masculine animal, has a masculine crest, and shows darkening of the hair in the region of the neck and crest, upper shank, lower ribs and on the thighs. He has clear, well-defined muscles on the neck, crest, upper shank, front ribs and on the stifle joint. The bull's color is not uniform and any breed society that puts down in its breed standards that bulls should be uniform in color, is treading on dangerous ground. The adrenal cortex of the animal gives off the male sex hormone, testosterone, which influences the sex libido of the animal. Research tends to show that androgen, the secretion of the testes, and adrenal cortex have an indirect influence on the darkening of the color of the hair on the animal. A bull should not be uniformly colored because he has to have masculine hair in all the regions mentioned. Figure 29 shows a bull's half brother, also 12 years old, castrated at two years of age. Since castration, his color turned uniform, lighter red than that of the bull. He has a rising chine because the ossification of the dorsal processes, that is the front vertebra, has not completely taken place. In every animal in

tile, the front ribs, thorax, chine, brisket, and head are the last parts of the body to reach maturity, that is the anterior half of the body, say from the sixth or seventh rib forward. The front ribs, the head, and horns continue to grow apparently until death. The steer castrated at six months of age (Figure 29) is 17 years old now and still shows a certain amount of growth in the length of ribs, head and horns. The bull's size, limited by the ossification of the long bones, was genetically as well as endocrinologically determined. The steer that was castrated at six

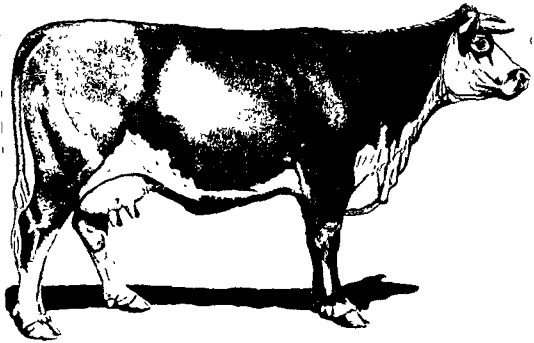


FIGURE 31. An example of a fertile cow.

months had delayed ossification of all the long bones which have an epiphyseal line and hence, his tremendous size. He is exceedingly tall and flat, over-developed anteriorly and underdeveloped posteriorly. This is the typical shape of any steer, not only *Bos indicus*, but of any breed. The stag or late castrated bull has a much more muscular upper shank than a steer. The steer's horns continue to grow. The anterior part of the mandible continues to grow because the body of the mandible is made up of epiphyseal cartilage which in the bovine never completely ossifies. The region of the rump is relatively small, it is short from the hip to the pinbones and it is relatively shallow from the hip to the patella or stifle joint.

The concept of what happens to the bone growth in the case of the fertile (Figure 31) animal as compared to the sub-fertile cow (Figure 32) is illustrated in these two figures. The scapulae or shoulder blades were *taken from two twelve-year-old* cows that have had eight calves and two that have had no calves. Note how much larger and heavier the shoulder blades of the sub-fertile cows are as compared to the scapulae of the highly fertile cows (Figures 33, 34 and 35). The cannon bones (meta carpus) were taken from the same cows, and note how much longer and

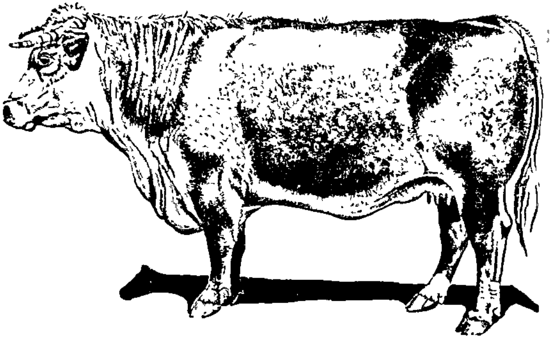


FIGURE 32. Example of sub-fertile cow.

heavier the bones of the sub-fertile cows are than those of the *highly fertile cows (Figure 36)*.

The principle of bone growth is illustrated in Figure 30 of a separated femur of a two-year-old heifer that has reached puberty but not quite complete sexual maturity. The epiphyseal line was still open. This animal, at the time of slaughter, had not conceived. The left femur was cleaned, cooked and separated at the epiphysis. The epiphyseal region would have shown more ossification if the animal had become pregnant and produced offspring. Bone growth stops in the fertile animal at the time of complete ossification of the epiphysis. (Bone growth stops in any animal when complete ossification has occurred.) The ossification of the epiphysis is delayed in the sub-fertile animal and hence,

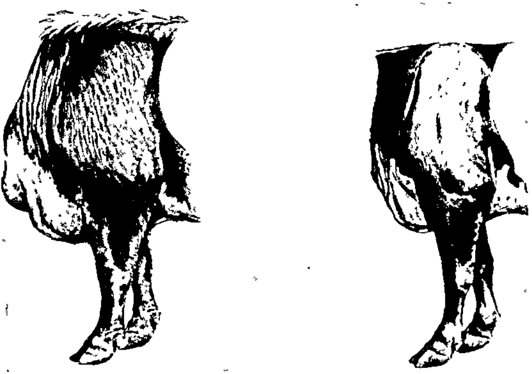


FIGURE 33. Front limbs of sub-fertile cow in left of photo and of fertile cow on the right.

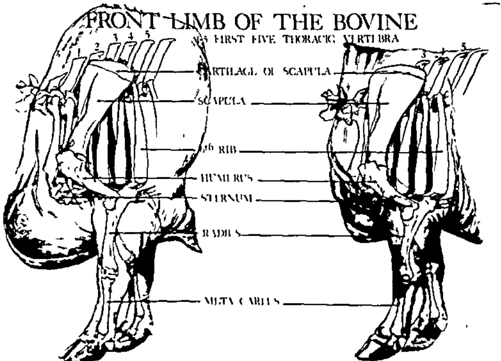


FIGURE 34. Front limbs of sub-fertile and fertile cow.

continues to grow. This explains why the sub-fertile animal is usually very tall.

The horn growth of steers and sub-fertile cows also continues indefinitely. The horns of a steer at Mara Research Station, South Africa, were measured from tip to tip every year from his fifth year until his death at nine years. Every year his overall horn length increased by approximately 3 inches. He had an overall horn length of 109 inches when he died. The horn growth

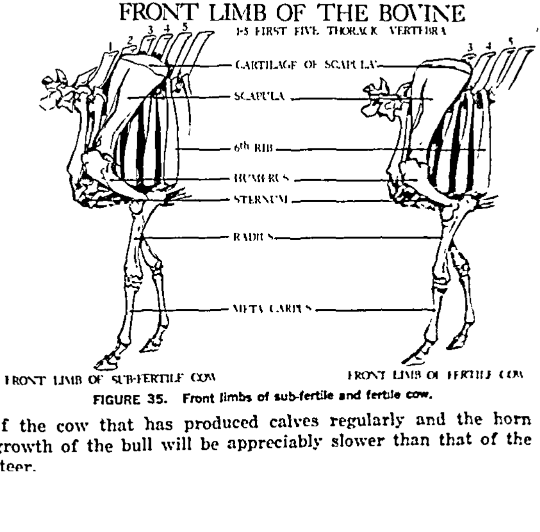


FIGURE 35. Front limbs of sub-fertile and fertile cow.

of the cow that has produced calves regularly and the horn growth of the bull will be appreciably slower than that of the steer.

female (Figure 37). Bulls with primary hypogonadism (small or infantile testes) possess potentiality for growing in height over a longer period of time than sexually active normal bulls because the deficiency of androgens cause a delayed ossification of the epiphyseal cartilages of the long bones, especially the front limbs and long ribs. The activity of the growth-promoting glands

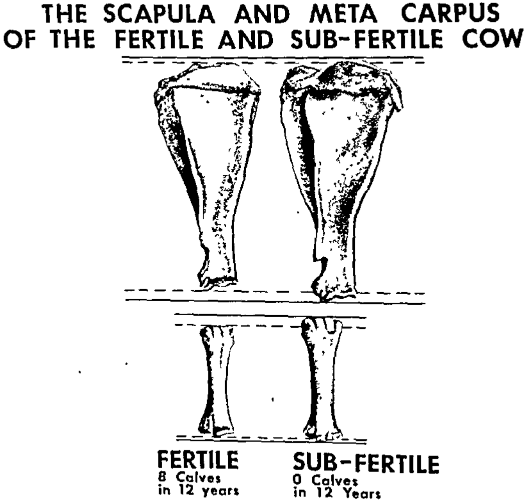


FIGURE 36. The scapula and meta carpus bones of a fertile cow on the left and sub-fertile cow on the right.

such as the pituitary, thyroid, etc., which is hereditarily determined, continues to produce hormones which determine whether or not excessive growth of the extremities will actually take place. The body proportions of the anterior development as compared to the posterior development can be used for distinguishing between various endocrine types.

The heifers by eunuchoidal bulls are often tall and bellow

like steers, and very often exhibit the same type of body proportions as their sires. The ossification of the long bones in such heifers is delayed as a result of lowered gonadal activity. They often are low-fertile animals, cycling irregularly with udder development that is infantile. The udder of a heifer that comes in heat regularly is more prominent.

It is known that the time of ossification of the epiphyseal cartilages depends on the maturation of the gonads, and hence, it has become customary to relate certain skeletal or body proportions to special endocrine patterns. In the human race, it is

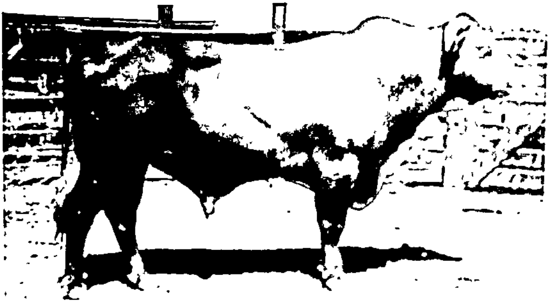


FIGURE 37. An example of an Eunochoidal bull

The moment you get a bull or a cow with the region of the thurls and thighs (mainly the regions through the rump, that is from the one thurl to the other) that is wider than the rest of the body, you can be certain that bull has eunuchoidal proportions and is often sub-fertile, and the cow that has the steerlike body proportions often has low fertility.

Figure 31 illustrates the form of the highly fertile animal. She has a good girth of chest. The floor of the chest is near the ground, or relatively near the ground. The rump, that is the area from the hip bones to the pin bones, is large, and from the pin bone to the stifle joint is deep. In the case of a sub-fertile cow (Figure 32) that has had three or four calves, the depth of chest is appreciably greater than that of the cow that has had nine or ten calves in the same time. The udder of the sub-fertile cow is functionally less efficient. It is also interesting to note how coarse the hair of the sub-fertile cow is. It is a much coarser hair than that of the fertile cow, especially from the middle of the back region to the crown of the head. Really coarse hair from the middle of the back to the top of the head, especially if that hair is darker and more bristly, is often indicative of a sub-fertile animal. The shape and skeletal proportions of the front limb is clearly illustrated by Figures 33, 34 and 35. The dorsal edge of the scapula is appreciably lower than the dorsal processes of the front vertebrae in the sub-fertile animal, and the scapula slants backward. The sternum is pushed down and slopes downward. All the hair on the neck is masculine, coarse, and heavy as compared with the hair of a fertile cow. The sub-fertile cow is relatively short from the hip to the pin and from the hip to the stifle joint.

The completely sterile cow again differs from the highly fertile and sub-fertile cow. Such cows have tremendous depth through the chest, the brisket is very full and the immediate effect is that it slopes forward and downward. The sterile cow has tremendous fleshing on the cheeks. The distance from the eye to the corner of the mandible is large and the lower jaw is relatively heavy. She has bristly hair on her body. The distance from the hip bone to the pin bone and from the hip to the patella is relatively small. The sterile or sub-fertile cow has a tremendously well-developed buffalo hump. It is well fleshed and fat. She has flesh and fat on the shoulders and a very full brisket. The floor of her chest is high off the ground, that means the

distance from the ground level to the floor of the chest is relatively large. The accurate scale drawings of the fertile (Figure 31) and the sterile cow (Figure 32) differ very markedly; the sterile cow is appreciably bigger as far as tallness is concerned than the highly fertile cow. The sterile cow is big in front, all the body parts in the anterior half of the body are much bigger in the sterile cow than in the fertile one. If you compare the hindquarters of the highly fertile cow with that of the sub-fertile cow, it is obvious that the pelvic region and rump of the fertile cow is appreciably larger than that of the sub-fertile one. So is the distance between the hip and the stifle joint appreciably larger in the fertile cow than it is in the sub-fertile cow. The overall size of a low-fertile animal is larger than that of the highly fertile one of the same breed, but the fertile one is much better developed and relatively much larger in the hindquarter than the sub-fertile cow.

The concept of differences in functional efficiency in cows is best illustrated in dairy cows. Every part of the body of the functionally efficient cow in front of about the sixth, seventh or eighth rib is lean. The trend in Europe is toward dual purpose cattle for the production of milk and meat. It is not necessary to go into dual purpose cattle—just select for beef the cattle that do not have too much fat on the shoulder and between the shoulder blades, that have balanced bone growth, secondary sex characteristics, and hair. Then we will have functionally efficient beef cattle.

Figure 38 shows an eight-and-one-half-year-old Jersey cow that has had seven calves in seven inseminations. The other cow in the diagram is eight and one-half years old and has had no calves and is typical of a functionally inefficient animal. The functionally inefficient cow has a round muscular neck with clearly defined muscles. There is no dewlap fold around the brisket. The hair from the crown in the center of the back is darker and bristly. The shoulders are fleshy. The body hair is often dry and coarse, and the hair on the udder is long and woolly. The hair on the sterile cow is often darker than that of a fertile cow. The adrenal cortex of the sterile cow in all probability gives off androgen hormone which is responsible for the darkening effect of the hair of the sterile animal.

That the sex hormones have a very marked influence on the quality and texture of the hair and hair shedding, can no longer

e doubted. In work done at the University of Pretoria it was ound that Friesland bulls and steers (bulls castrated at 8 nonths) differed very markedly in the quality and texture of the air and in their muscle development. The bulls have sleek, waxy

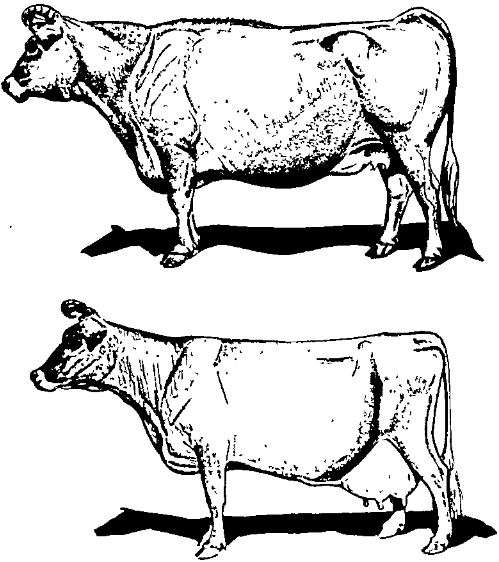


FIGURE 38. Top cow has had no calves while bottom cow has had 7 calves. Both are 8½ years old.

hair, the steers, dry and longer hair. The muscles in the upper shank region are well developed in the bulls. They have masculine crest development and their muscles are clearly defined. A male should have clearly defined muscles; the smooth animal is often eunuchoidal. The steer has very little masculine hair on the opening of the penis, his neck is thinner, there is no round

and muscular crest development. If a fourteen-month-old bull is compared with a fourteen-month-old steer (Figure 39) it is obvious that they differ with regard to size and body conformation, muscularity, hair quality and texture. The hair of the young bull is lively and sleek, while that of the steer is dead and dull. The relative positions of the shoulder blades also differ in these animals. The scapula of the steer is in a backward slanting position. The legs of the steer are appreciably thinner than those of the bull. At the age of fourteen months, the bulls, on an average, weigh 80 pounds more than the steers.

The influence of the sex hormones on the hair growth and hair shedding of cows and heifers is most important. The cow sleeks

FIGURE 39. Note the difference in conformation of a 14 month old bull (left) and steer (right) of the same age.

off immediately when she becomes pregnant and remains sleek throughout lactation. The open cow and sub-fertile cow that is not pregnant does not sleek off. Her hair grows and sleeks off only when she is pregnant or is functioning efficiently. We can change the hair coat of an animal artificially by the injection of sex hormones. Heifers treated with sex hormones such as stilbestrol shed their coats within three weeks. The moment an animal becomes pregnant, a narrow line on the spine becomes very sleek and darker. The thin line along the spine is very glossy, and almost looks as if the cow has been rubbed with an oily rag. The sleeking off also takes place in steers or open heifers when they are in good health, have a good nutritional status, and the climate is getting warmer. The sleeking off, however, is not nearly as well defined as in the case of a pregnant cow or heifer. Figures 40, 41, and 42 show examples of highly fertile cows.

There is no pattern in the hair of the low fertile or sterile animal. There is often no real sleeking off and there is no darkening of the hair on the spine right on top of the back.

The color and texture of the horns of fertile and sub-fertile or sterile animals differ very much. The horn of the fertile animal is uniformly colored and often looks waxy. The horn of the sub-fertile or sterile animal is hard and flinty, and it often has

FIGURE 40. A highly fertile Brahman cow. Note the leanness of shoulder. The skin-fold along the brisket, i.e. the dewlap around the brisket is free from fat deposits. Note the position of the scapula relative to the top of the chine.

ossified white rings or patches which are very smooth, porcelain-like and very hard. Figures 43, 44, and 45 illustrate low fertility cows.

The cow that has aborted often develops the extremely smooth, hard white spot or rings on the horns. The brisket is often full with lumpy patches of fat on the brisket. A buffalo hump develops, and the hair becomes darker and bristly. The hair on the head, neck, shoulders, and lower thigh regions is coarse, dull, and dry. Fat in front of the udder and a longitudinal lump below the vulva are typical characteristics of the sub-fertile cow and the aborter shows irregular lumps of fat which are probably harder and encapsulated. Figures 46 and 47 illustrate low fertility cows which have aborted.

FIGURE 41. A highly fertile Sanga cow (Bos indicus) which is twelve years old. Has had 8 calves. *Note the feminine head, lean cheeks and light mandible. Also note the* feminine neck covered with fine hair. She has no crest and a lean brisket.

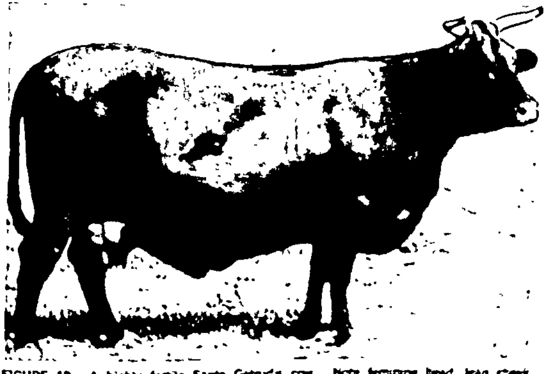


FIGURE 42. A highly fertile Santa Gertrudis cow. Note feminine head, lean cheeks, flat neck, lean brisket and shoulders. Also note the length from the hip to the pin bones. She has a very good functional udder.

In the case of a pair of identical twin heifers, both of which were repeat breeders or sub-fertile heifers, they succeeded in getting one pregnant after four inseminations. The sub-fertile one that calved differed very much from the sterile one. The two heifers differed in body conformation afterwards. The one that calved had a much leaner face, not such a heavy lower jaw, a lean neck and a skinfold around the brisket. They differed in

FIGURE 43. Low fertility cow. Note the forequarter of a typically low fertility or sterile young cow. Note the muscularity of the neck and the smooth, full protruding brisket. If the animal had aborted the brisket would be lumpy.

coat cover; the fertile one was much sleeker than the one that did not calve.

The animal that has become sub-fertile or sterile or the animal which calves irregularly (that is cows which have intercalving dates of eighteen months and more) develop certain characteristics which are indicative of endocrine imbalance and upset metabolism. The cow develops certain characteristic fat deposits on the body (Figure 48). The first is on the lower cheek, the second on the brisket; the brisket becomes full, the whole dew-

lap disappears and there is no skinfold around the brisket. The cow develops a buffalo hump on the chine, an ovalshaped lump of fat on top of the shoulder blades. Usually a tremendous amount of flesh and fat is deposited between the scapulae or shoulder blades. An oval fat deposit develops on the lower ribs and a very heavy fat deposit on the hip bone. The fat on the hip bone is a very solid type of fat; it is a sort of *immobilizable fat* which becomes almost as hard as cartilage when the animal

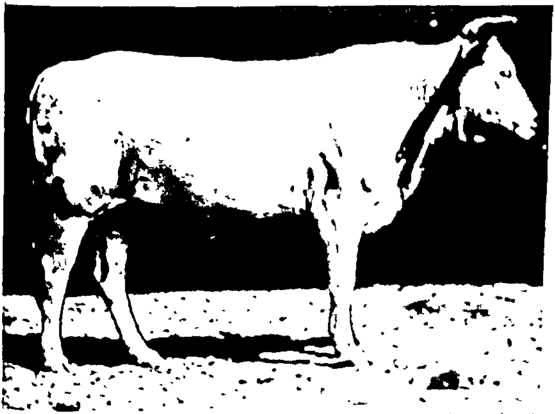


FIGURE 44. A Sanga (Bos indicus) cow which has the [illegible] of a [illegible] or sterile animal! She is 12 years old and has never calved. She has a [illegible] head and neck with clearly defined muscles and crest and heavy cheeks. She is long legged, flat over the ribs, deep through the chest and shallow through the flank.

FIGURE 45. A typical low fertility cow. Note the roundness of neck, the rising crest and the very full smooth sloping brisket. Note the tremendous amount of fat deposit over the center of the back. She is short from hip to the pin bones and from the hip bone to the patella (stifle joint). The udder lacks functional efficiency.

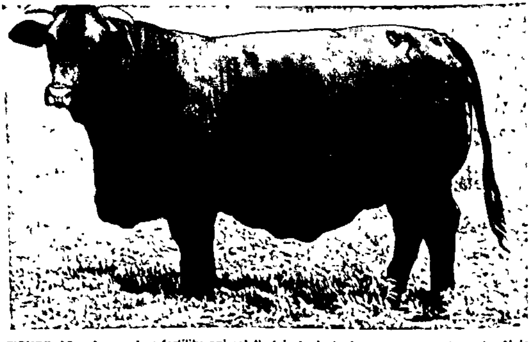


FIGURE 46. A very low fertility animal that is typical of one that has aborted. Note *the brisket which is protruding, sloping forward and lumpy. Note the bristly hair on* the neck and chine, the typical lump of fat below the vulva and the rounded hindquarters.

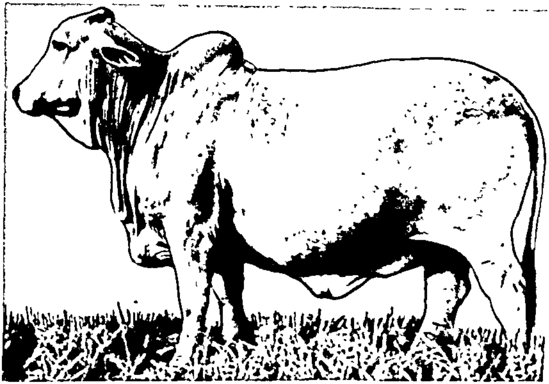


FIGURE 47. A typical low fertility Brahman. Note the full brisket and the lumpy fat deposits on the lower regions of the scapula. This cow has never suckled a calf but has aborted twice. The udder shows she was pregnant but her teats show that she has never suckled a calf.

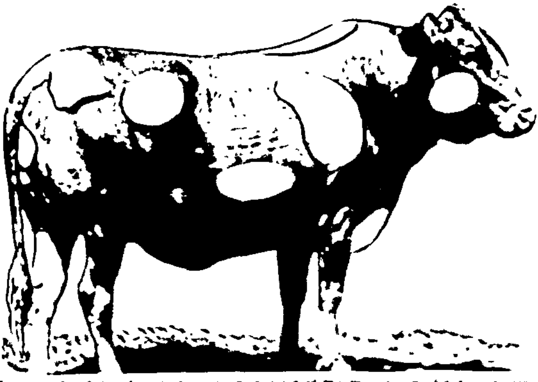


FIGURE 48. A low fertility cow on which most of the characteristic fat deposits are marked in white.

also shows characteristic changes in her morphology. The brisket drops forward and downward, and it loses the skinfold off of the dewlap around it. The cow that has been fertile and then gone sterile develops a peculiar body conformation in the hindquarters. She is completely round in every direction, from directly behind and from the side view. Such an animal's vulva often becomes infantile, that is, as a result of discontinuing of reproductive function, hypoplasia of the genitalia takes place. A definite oval lump of fat develops in the region below the vulva. The hindquarters resemble a big ball cut in half and placed at her rear end. If animals become so rounded in the hindquarters that they resemble a horse's buttocks, it becomes doubtful if such an animal will settle readily. Many typical show heifers have tremendously developed hindquarters which look as if they are protruding posteriorly. They have much fat development in front of the udder, the brisket is too full, a darkening of the hair takes place, especially in the region of the neck, upper shank and lower thighs. If a cow or heifer's tail cannot hang down perpendicularly, it is doubtful whether she will settle readily. A cow or heifer that settles with one insemination, has square hindquarters and the tail hangs down perpendicularly. Her brisket does not protrude forward and downward.

The livestock industry has had this problem of over-fat, subfertile cows for a hundred years or more. This is shown through the illustrations of show winning cows of 1865. An illustration of a show champion cow in South Holland is that of an absolutely low fertile cow. She has tremendous development in the front region, is small in the rear, has a heavy crest, a rounded neck, and full face. Those animals that are regular show winners are those that have problems with regard to fertility and yet have conformed to show standards for generations.

An illustration of a show winning Shorthorn cow is typically that of a low fertile cow with a full brisket with no dewlap or anything around it, a round neck, deep through the region of the chest where it should not be deep, and shallow through the region of the flank where it should be deep. The udder is infantile for that of a large cow. The low or sub-fertile cow often has a dark line of bristly hair on the top of the neck and crest, and a full brisket. The animal that has aborted often has patchy lumps of fat on the brisket. The brisket is not smooth and the teats very often show that the udder has developed to a certain ex-

tent and then receded, which is indicative that the cow has aborted. The cow that loses a calf before suckling it for a few months or the cow that aborts, develops a white porcelainy mark on the horns. If too much stress is placed on growth in an animal, an imbalance between the somatotropins, that is the growth hormones, and the gonadotropins, that is the sex hormones, is struck and hence, fertility is lowered.

At the McGregor Station, a Hereford bull was treated with a female sex hormone, stilbestrol, by implantation of stilbestrol in the neck. The bull started sleeking off in three weeks' time, the hair color became lighter and his head became completely feminine. He showed the typical syndrome of gynecomastia, that is the development of female teats and hair completely different to that of the control bulls.

The female sex organ, the vestibule of a cow that has been treated with male sex hormones, developed a very large clitoris. If a heifer's vulva points downward and protrudes posteriorly and is very large, it is indicative of an imbalance of the female sex hormones and of the clitoris being very large. Such females often come in heat irregularly. It is possible to select heifers for functional efficiency before they are exposed to the bull for the first time. The fertile heifer looks feminine, has a normally developed vulva, and the udder is well developed and indicative that she is cycling regularly. The sub-fertile heifer is usually very large in size, looks masculine, has a masculine or steery head, an infantile vulva and udder. She has bristly hair on the back, is deep through the chest, and has a downward, forward protruding brisket. She does not cycle normally. In an old cow that calves regularly, it is noted the horns are usually and evenly a grayish color with no hard smooth patches. The regular calver has a lean face, an absolutely lean neck, a skinfold right around the brisket and the top of her shoulder blade, and a scapula which is higher than the highest points of the spinous processes of the dorsal vertebrae. Such a cow has tremendous stomach capacity and a well developed udder that is functionally efficient. The animal that is really functionally efficient has small, sleek, and very shiny teats. Her tail hangs down perpendicularly. The moment a cow gets heavy in the region of the brisket and on the shoulders, it is certain that she does not calve regularly and is a poor producer of milk if she calves.

Figure 49 is a diagram of two Brahman cows, drawn accurate-

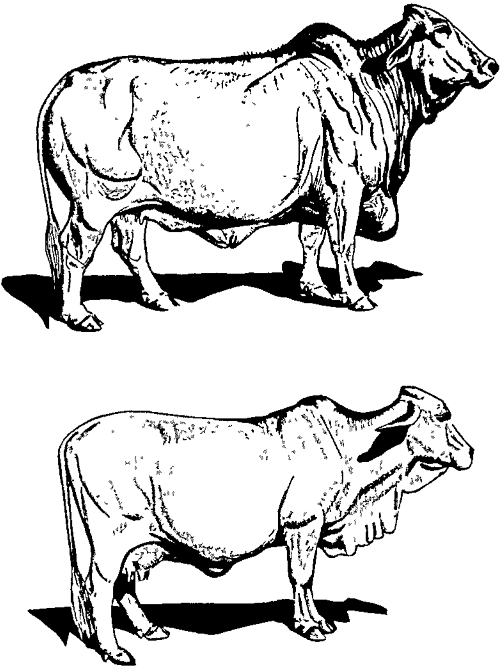


FIGURE 49. Bottom cow has had 11 calves and the other has not raised a calf.

ly to scale. One cow has had eleven calves in thirteen years, the other one has had two abortions and has not raised a calf. The cow that has aborted has lumps of fat on the brisket and has an udder that indicates it has not functioned properly. She has a development of fat on the shoulders, ribs, and hipbones. In other words, she has the conformation of the low or sub-fertile animal.

Figure 50 comes from a cow that is 12 years old and has had 8 calves. *The horn of her uterus indicates that it is functioning normally. There is a corpus luteum on the one ovary and a* ripening Graafian follicle on the other. Figure 51 comes from the half-sister of the 12-year-old cow that has had 8 calves, but this cow has had no calves. She is large, masculine looking, with a heavy head, dull and dead hair on the neck and on the regions of

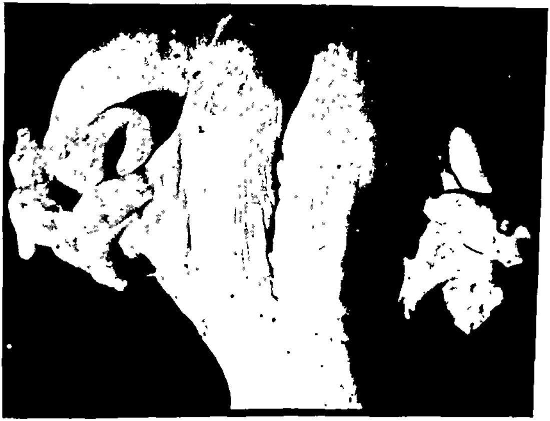


FIGURE 50: Uterus of a 12 year old cow that has had 8 calves. Note the corpus lutem on the right ovary and the maturing Graafian follicle on the left.

the flank and rump. She has no udder development (an absolutely infantile udder). Her complete reproductive tract, photographed from the same distance as that of the animal that has had 8 calves, is completely infantile.

In a functionally efficient bull, there is a darkening of the hair. Even in the case of an Aberdeen Angus bull, there should be masculine black hair on the neck and crest. A bull must have a well-muscled, masculine crest, with well defined muscles in the neck. *A masculine* bull should have well defined *muscles* on the upper front limb and well defined muscles on the patella or

stifle joint. The testes should be well developed. A too loose, extensive sheath development is most undesirable. Viewed from behind, the fertile bull has well sprung ribs, and the lower rib region is the widest part of the body.

Figure 54 shows a Brahman bull that has a good pair of testes. In most lectures on the sex physiology of bulls, it unfortunately is customary to start with the internal anatomy of the sex or-

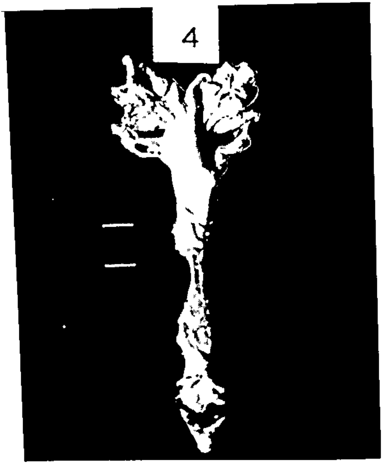


FIGURE 51. Infantile reproductive tract of a 12 year old cow.

gans by showing cross-sections of the various organs. The external male sex organs such as the testicles, scrotum, sheath and penis are most important and of great value in evaluating the animal's sexual potential. Then one should take off the skin and cut the animal in two to show the internal anatomy. It is so much more interesting and so much more revealing to judge the external anatomy first and interpret the visual appraisal in terms of sex physiology.

The scrotum is a most delicately arranged thermo-regulatory

mechanism. It has the function of keeping the testes cool when hot, and if it is cold, to keep them warm. The scrotum can pucker up when it gets cold. The skin of the scrotum can withdraw and form skinfolds which make the skin an appreciably better heat retaining organ, by reducing the surface area and entrapping air in the skinfolds; it also draws the testis almost into the abdominal cavity of the bull.

Harrison of Liverpool University and I did quite a bit of work on the thermo-regulatory mechanism of the scrotum and vascular system of the reproductive organs of bulls. The spermatic arteries and veins have a thermo-regulatory function. By putting Chlor-Bismuth, that is a radio opaque substance, in the spermatic vein and then taking X-ray photographs of the testis, it was obvious that the vascularity of the testes of bulls adapted to temperate zones differed very markedly from those of bulls adapted to tropical and subtropical regions. The animal whose scrotum and testes have a really good thermo-regulatory mechanism has tremendously tortuous spermatic vein development which enables the animal to maintain the temperature of the testes. If the testes become too large and pendulous and swing about and get injured, a varicocele develops that blocks the vein and the whole thermo-regulatory function is impaired and the animal becomes sterile.

Figure 52 is a photograph of the testes and sex organs of a bull that indicates severe hypoplasia of one testicle and another testicle that is over-developed. The penis shows prolapse of the prepuce, far too much sheath development and a large opening in the sheath. These defects are hereditary. In the Polled Swedish Mountain breed, two show winning bulls with one hypoplastic testicle and one normal testicle almost ruined the whole breed of cattle by producing sub-fertile female progeny.

The difference between the development of the hindquarters of a hypoplastic eunuchoidal (steer like) bull (Figure 53) and a normal bull (Figure 54) are shown by these two figures. The normal bull has a pair of normally functioning testicles with a well formed epididymis, while the eunuchoidal bull has a pair of completely hypoplastic testicles (Figure 55). This syndrome is hereditary.

Recently I encountered hypoplastic bulls on one ranch and all three were the sons of a hypoplastic bull. The sire had only produced 7 offspring in 1964, and his three sons had produced

FIGURE 52. The small testicle shows severe hypoplasia whereas the other is over-developed.

FIGURE 53. Hypoplastic testicles of a eunochoidal (steer-like) bull.

no progeny in 1964. At a Brahman ranch a very tall bull produced many tall sub-fertile type heifers. In Sweden, two bulls that were regular show winners were used extensively. They were half-brothers and both were hypoplastic. Thirty years later this breed was found to be sub-fertile. In an endeavor to overcome this problem, 8,000 heifers were slaughtered and no fewer than 1,070 were found to be sub-fertile and to have abnormalities of the genitalia with either one or both ovaries being abnormal.

Very straight hocks in a bull are objectionable. Such bulls have high thurls (top of the trocharter major), and the joint of

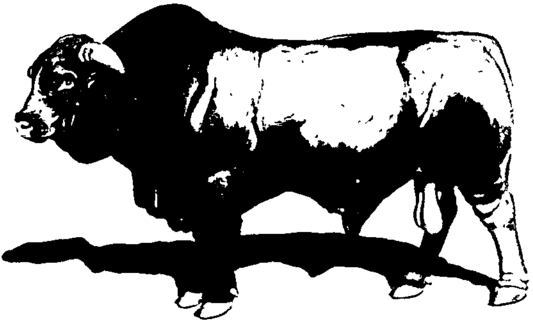


FIGURE 54. Normal bull showing a pair of normal functioning testicles

Heritable defects such as weak pasterns interfere with the bull's ability to serve and so do weaknesses such as corns between the rear hooves. The sperm testing of bulls is no index of their ability to settle cows, unless we are certain they have no defects which will interfere with their serving ability. Semen quality and a semen test are not the answer to whether the bull

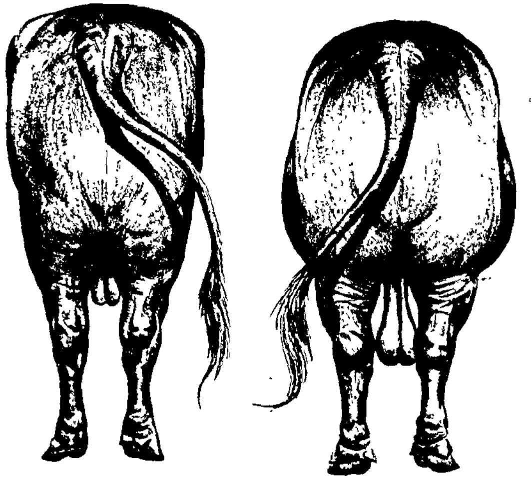


FIGURE 55. Hind view of the eunochoidal bull (left) and the normal bull (right) shown in Figures 53 and 54.

is fertile and whether he will have many calves. The sperm test and the sperm evaluation of a bull's semen are important, but the bull must be inspected and observed to determine whether he has certain physical disabilities and sex drive or libido. The electroejaculator can get semen out of a bull but it is no index of his ability to serve. A physical defect such as corns between the hooves is a serious handicap to the bull's ability to walk and to serve a cow. Corns between the rear hooves are

BACK LIMB OF THE BOVINE

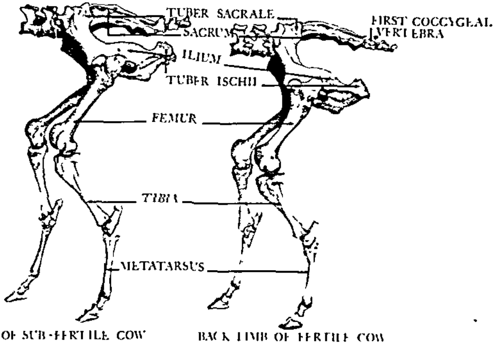
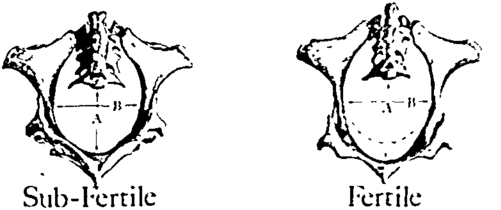


FIGURE 56. Back limbs of sub-fertile and fertile cows. Note the larger opening of the pelvis in the fertile cow.

PELVIC LIMB OF THE BOVINE



A is the result of a higher Acetabul[illegible] Femur [illegible] Art[illegible]
Distance between Median Crest of Sacrum [illegible]
as a result of higher Acetabul[illegible]
Dotted Line indicates [illegible] the pel[illegible]
the sub-fertile an[illegible]

FIGURE 57. Note the smaller pelvic opening in the sub-fertile cow

especially undesirable. The moment that a bull with corns mounts a cow, the corns hurt and the bull withdraws before the act of mating is completed.

Arthritis is another heritable defect; it is caused by a disturbance in the steroid metabolism. It is closely correlated with reproductive impairment. The sex hormones and fluids are products of steroid metabolism and any animal that has arthritis should not be used in a breeding program. Several herds in this country have bad arthritic bulls in use. Some badly affected arthritic bulls are kept at bull hotels where the semen of these bulls is obtained by the electroejaculator and semen banks are built up for future use. A disservice is done to the breed by propagating these arthritic inclined livestock. In the case of one arthritic bull in the United States, I saw thirteen of his heifers and eleven had to be culled as a result of being low in fertility and arthritic.

Double muscling in cattle is a serious problem. Not only are double muscled cattle lower in fertility, but calves by double muscled bulls cause calving difficulty. I am not interested in any bull which has abnormal muscle development anywhere. Bulls which are not balanced as far as body conformation is concerned, especially when they have relatively large, long heads and very deep forequarters, are inclined to cause calving difficulties in the cows.

The sex hormones have a direct influence on the coat color, the sleekness, and the darkening of the hair in the bull. Bulls with sleek hair and darkening of the hair on the neck, upper shanks, and thighs usually have greater sex libido than bulls with dull, evenly colored hair coats. The darkening of the hair and the coarsening of the hair on the neck—a definite masculine secondary sexual characteristic—is caused by the androgens given off by the testes and adrenal cortex. If a bull's color on the darker regions of his hide fades, the bull will become less sexually active. A highly fertile bull with good libido usually has tremendous darkening of the hair in particular regions of the body. It occurs in the neck, the upper forearm or upper front leg, along the brisket, the lower rib area and the sides. Bulls that are dark in those areas usually have tremendous sex activity.

You may ask the question, why does it help you to know how to judge cattle for functional efficiency? If you know whether a heifer is going to be highly fertile when you select her, and if

you know that a heifer will settle on one service or very few services, it saves bull power on the ranch and it increases calving percentage. One particular ranch on which cattle were selected for many years, had an average calf crop of 70 per cent for thirteen years. Then in 1956 all animals were appraised for functional efficiency and all animals, heifers, cows, and bulls, that seemed functionally inefficient were culled. A total of 349 cows out of 2,669 were butchered. The owner was perturbed about having to cull 349 at this stage; he thought he would never have a large calf crop again. The calf crop jumped to 87 per cent; then 85, 87, 90, 92, 93, and 93 per cent. The year after the culling, this ranch produced 170 calves more than ever before produced and the overall income increased by $40,000.

By applying our knowledge of judging livestock for functional efficiency and by using this tool hand-in-hand with performance and progeny testing, we will greatly improve livestock production.

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21

R. E. DEESE
M. KOGER

Heritability of Reproduction

The ability of the cow to conceive at regular intervals, provide an optimum environment for the growth of the fetus, and give birth to a normal calf are factors of prime importance to success in the beef cattle business. According to United States Department of Agriculture statistics, the average calving rate in cows and heifers two years of age and older for the United States as a whole was 86 per cent in 1967. The corresponding estimate for Florida cattle was 76 per cent. This means that Florida cattlemen are averaging 10 calves less at birth per 100 cows bred than the average cattleman in the United States. Much of this difference may be due to genetic differences in the cattle populations of Florida and other parts of the nation which could result from natural stresses working against efficient reproduction in Florida cattle. If genetic factors are involved, then selection for high reproductive rates should be beneficial from the standpoint of increasing the calving rate and, consequently, the gross income from the cow herd.

Reported Studies on Reproductive Traits

Heritability is the percentage of the total variability of a trait that is influenced by genetic factors and passed on to the offspring. The higher the heritability estimate, the greater the opportunity for genetic improvement by selection. Reported estimates on heritability of reproductive traits in beef cattle are few in number. Traits such as calving interval, time from parturition to first estrus, number of services per conception, and per cent

of non-returns to first service have been investigated rather extensively in dairy cattle and to some extent in beef cattle.

There are evidences of a general nature and from many sources which suggest that genetic factors affecting reproduction are differences due to breed groups, sire progenies, and cow families. Reynolds (1960) and Koger *et al.* (1962) reported highly significant breed group differences in the number of calves born and the number weaned per cow bred in a study involving straight-bred British and Brahman cattle and various crosses of these breeds. Warnick *et al.* (1960) studied the rate of reproduction in 10,170 cows from experiment station and privately-owned herds in Florida over a five-year period and found that Brahman and crosses involving Brahman cattle had significantly lower pregnancy rates than British breeds. Spielman and Jones (1939) reported marked differences in reproductive efficiency between four of the major breeds of dairy cattle and between various cow families within these breeds based on age at first calving and regularity of calving. They found a correlation of 0.55 between the reproductive efficiency of foundation cows and the average of their daughters.

Käb (1937) studied records of 7,104 calvings in dairy cattle in Germany and noted differences between the fertility of groups of cows sired by different bulls. High fertility was evident in 35 groups and low fertility was present in 11 groups. Trimberger and Davis (1945) examined the breeding records of the daughters of 19 dairy bulls used in the Nebraska Experiment Station herds and found the daughters of one bull required a significantly greater number of services per conception than the average, and another group closely approached this level. They also noted that in 20 cow families, one had very low fertility and two had extremely high fertility, based on services per conception. Mares *et al.* (1961) found that the line of sire of the cow had a significant effect on conception rate in a Wisconsin Experiment Station herd of Holstein cows as determined by rectal palpation 35 days after breeding

on non-returns to first service in a population of half-sib cows within the same dairy herd to be 0.004. When calving interval was used as a measure of fertility, heritability was estimated to be zero.

Recent Studies in Florida

Records from a purebred Brahman herd and a crossbred foundation herd, which were accumulated over a period of 15 years, were recently analyzed by Deese (1965) for heritability of calving rate. The crossbred herd was of Shorthorn-Brahman breeding and was maintained as a closed herd throughout this period.

The two herds were maintained under similar conditions and management practices with the breeding season extending over a period of four or five months. Annual individual calving records were maintained for all cows in the breeding herd, and the pregnancy status of all cows eliminated from the herd was determined. A cow which gave birth to a calf or was pregnant when sold was given a code of one (1) and all others were coded zero (0). These values were used as observations in the statistical analysis for estimating heritability.

The various methods for estimating heritability were based upon the resemblance between closely related individuals as compared to the resemblance between nonrelated or less closely related individuals. Both genetic and environmental sources of variation contribute to the likeness of individuals. The accuracy of heritability estimates depends on the accuracy with which these components are measured. Statistical procedures for estimating the components of variation are described in many publications and details of such are not considered practical for this presentation.

the same breeders cooperative in Wisconsin, Inskeep *et al.* (1961) found conception rates ranging from 43 to 94 per cent in 27 paternal half-sib groups of heifers and a range of 33 to 91 per cent in 36 paternal half-sib groups of parous cows. Heritability of conception rate based on birth of a live calf from first insemination was 0.085. Olds and Seath (1953) studied 472 normal parturitions of 210 dairy cows in the Kentucky Experiment Station herd and estimated heritability of time from calving to first estrus to be 0.27 and 0.32 by intra-sire daughter-dam regression methods, using first records only and average of all records, respectively. Paternal half-sib correlation of average records revealed heritability to be 0.31.

In a study involving 537 Holstein-Friesian cows over a 30-year period in Maryland, Wilcox *et al.* (1957) found heritability of breeding efficiency, based on daughter-dam regressions, to be 0.32. Contrary to the above reports, which suggest genetic differences in reproductive traits, other workers have reported extremely low or zero heritability estimates for these traits. Lindley *et al.* (1958) studied the reproductive performance of a purebred Hereford herd in Oklahoma and found heritability for such traits as services per conception, calving interval, and intervals from calving to first breeding, first breeding to conception, and calving to conception ranging from zero to 0.07 by paternal half-sib correlation methods. Estimates based on daughter-dam correlations and regressions ranged from -0.24 to 0.30 which were interpreted to mean that the true estimates were near zero. Brown *et al.* (1954) reported that heritability of calving interval in an Angus herd mated for year-round calving under range conditions in Mexico was practically zero by half-sib correlation and daughter-dam regression methods. Warnick (1955) found no significant breed or line effects on interval from parturition to first estrus in the Angus and Hereford cows of the Oregon State College herd.

Olds and Seath (1950) reported a very low correlation of 0.084 for breeding efficiency in consecutive years based on number of services per conception in dairy cows and concluded this to be too low for predictability. Legates (1954) studied the breeding records of 1,129 dairy cows and estimated heritability of services per conception to be 0.026, while 2,419 calving intervals for 1,016 cows revealed a heritability estimate of 0.133. Dunbar and Henderson (1953) estimated heritability of fertility based

on non-returns to first service in a population of half-sib cows within the same dairy herd to be 0.004. When calving interval was used as a measure of fertility, heritability was estimated to be zero.

Recent Studies in Florida

Records from a purebred Brahman herd and a crossbred foundation herd, which were accumulated over a period of 15 years, were recently analyzed by Deese (1965) for heritability of calving rate. The crossbred herd was of Shorthorn-Brahman breeding and was maintained as a closed herd throughout this period.

The two herds were maintained under similar conditions and management practices with the breeding season extending over a period of four or five months. Annual individual calving records were maintained for all cows in the breeding herd, and the pregnancy status of all cows eliminated from the herd was determined. A cow which gave birth to a calf or was pregnant when sold was given a code of one (1) and all others were coded zero (0). These values were used as observations in the statistical analysis for estimating heritability.

The various methods for estimating heritability were based upon the resemblance between closely related individuals as compared to the resemblance between nonrelated or less closely related individuals. Both genetic and environmental sources of variation contribute to the likeness of individuals. The accuracy of heritability estimates depends on the accuracy with which these components are measured. Statistical procedures for estimating the components of variation are described in many publications and details of such are not considered practical for this presentation.

1. Paternal half-sib correlation of first records only from three-year-old cows, all of which were nonlactating during the breeding season.

2. Paternal half-sib correlation of second records only from four-year-old cows, all of which were lactating during the breeding season.

3. Paternal half-sib correlation of lifetime average calving records for all cows in the herds.

4. Intra-sire regression of daughter's lifetime average record on the lifetime average record of her dam.

TABLE 64.—MEANS AND HERITABILITY ESTIMATES FOR BIRTH RATE BASED ON PATERNAL HALF-SIB CORRELATIONS OF SINGLE RECORD:

BASIS FOR ESTIMATE	MEAN BIRTH RATE	H²
Brahman Herd		
First record only	0.83	0.31
Second record only	0.62	0.21
Crossbred herd		
First record only	0.80	0.63
Second record only	0.51	0.56

Since the observed individual birth record was an all-or-none characteristic (the cow either had a calf or did not have a calf), the within-subgroup variance of single records in methods one and two above was correlated with the mean birth rate of the population. Therefore, statistical procedures described by Lush *et al.* (1948) were used to derive heritability estimates from analyses 1 and 2. No transformation was used in methods 3 and 4 since the observations used were means, and approximate normality of distribution was assumed.

The variance analysis of first and second single records revealed significant effects for sire of cow on the birth rate in the crossbred herd. Sire effects approached significance in the Brahman herd. Mean birth rates and heritability estimates (h^2) based on single records are shown in Table 64. The mean birth rates of 83 and 80 per cent for the first-record cows in the Brahman and crossbred herds, respectively, are probably higher than the general average for cows of similar age and breeding in Florida. The mean birth rates for second-record cows were considerably lower at 62 and 51 per cent for the two herds, respectively. These lowered birth rates in second-record cows are

not surprising in view of the findings of Reynolds (1960), Warnick *et al.* (1960) and Koger *et al.* (1962) which showed that lactating cows of Brahman breeding had significantly lower conception rates than nonlactating cows of similar breeding. Heritability estimates based on single records were 0.31 and 0.21, respectively, for first- and second-record Brahman cows. Corresponding estimates for the crossbred cows were 0.63 and 0.56.

TABLE 65.—NUMBERS, MEANS AND HERITABILITY ESTIMATES FOR BIRTH RATE BASED ON PATERNAL HALF-SIB CORRELATION OF LIFETIME AVERAGES FOR COWS

HERD	NUMBER OF SIRES	DAUGHTERS PER SIRE (AVERAGE)	RECORDS PER DAUGHTER (AVERAGE)	MEAN BIRTH RATE	H^2
Brahman	45	7.3	5.0	0.82	0.39
Crossbred	23	10.6	3.9	0.74	0.39

Sires significantly affected the birth rates of their daughters in both herds when lifetime averages were used. Heritability estimates by paternal half-sib correlation methods are shown in Table 65 and were 0.39 for both herds. The average number of daughters per sire and average number of records per daughter differed some in the two herds but these differences were not great. The numbers were considered to be adequate for reliable estimates in both herds.

TABLE 66.—NUMBERS AND HERITABILITY ESTIMATES FOR BIRTH RATE BASED ON DAUGHTER-DAM REGRESSION OF LIFETIME AVERAGES

HERD	NUMBER OF PAIRS	RECORDS PER DAUGHTER (AVERAGE)	RECORDS PER DAM (AVERAGE)	H^2
Brahman	194	4.0	8.7	0.54
Crossbred	245	3.9	8.0	0.25

methods are fairly large but are not unusual. These differences could be due to sampling error or to inability to remove certain environmental effects in some of the analyses. It seems reasonable to assume that single records gave the most reliable estimates because of the elimination of known environmental influences such as age and lactation status.

All estimates of heritability in this study were considerably higher than those reported previously for traits related to fertility in beef cows. This may be due partially to population differences as well as differences in methods of analyzing the data. The low estimates of heritability reported by Lindley *et al.* (1958) and Brown *et al.* (1954) for reproductive traits were based on cattle of European origin. The extremely wide differences in the histories of European and Zebu cattle have probably resulted in stronger selection pressure for high reproduction in the European breeds through natural forces and management practices. Any practice, natural or man-made, which would tend to reduce variation, would likewise reduce heritability. On the other hand, the generally low levels of nutrition in Florida have resulted in natural stresses working against high reproduction. Other factors such as lactation stress and restricted breeding seasons may be involved.

The results from this study suggest that in unfavorable environments where the mean reproduction rate is suboptimal, heritability for this trait is high enough in many populations that significant genetic progress can be made through selection and culling procedures.

CONCLUSIONS

Even though estimates of heritability of reproductive traits from different locations and by different methods assume a wide range of values, there are strong indications that traits such as calving and weaning rates are heritable. In herds which are below average in reproductive efficiency, selection of replacement animals from regularly producing cows and culling cows which fail to reproduce every year will likely result in significant progress when other management practices are adequate.

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M. KOGER

Selection and Culling in Florida

Most published reports show that the heritability of reproductive performance is extremely low. This simply means that progress would be very slow in herds where reproduction is good. However, in herds where average reproduction is low, such as is evident in Florida, heritability can be high enough to show great progress in this trait when effective selection is practiced. It has been shown in both experimental and commercial herds in Florida that culling for reproductive failure can dramatically change the average reproductive performance of a herd.

The principal achievements realized through culling cows for reproductive failure include the following:

1. It maintains selection pressure for improvement in genetic potential for high reproductive efficiency.

2. It puts a positive control of removing infertile females. Such animals are expensive to maintain and contribute nothing to economic returns.

3. Cows with the tendency for alternate year breeding are removed. Females with this tendency are common in Florida cattle populations.

4. Animals are removed which fail to reproduce because they are unthrifty or poorly adapted to the area.

5. Culling cows for reproductive failure is an extremely effective procedure in helping control venereal diseases and possibly numerous undetected low grade infections.

6. With the prices usually prevailing in Florida, it is to the immediate, as well as to the long term, advantage of the rancher to sell nonpregnant cows and replace them with heifers. A non-

pregnant cow will generally sell for more than the cost of a replacement heifer. More beef and greater economic returns can be realized through culling nonpregnant cows, even if reproductive efficiency were not improved (Table 71).

The most effective procedure for most ranch operations in culling cows for reproductive failure is to breed cows in a restricted season (there is no apparent advantage in a season of more than 75 to 90 days with good reproductive efficiency being obtained in many herds with breeding seasons as short as 45 to 60 days), palpate for pregnancy at weaning, and remove all nonpregnant cows. Depending upon pregnancy rate at the initiation of the culling program, it may be necessary to give the better cows a second chance until pregnancy rate is increased to the point where all nonpregnant cows can be culled. The major advantages of culling during the fall on the basis of palpation are:

TABLE 67.—IMPROVEMENT IN REPRODUCTION UNDER CULLING AT THE BEEF RESEARCH UNIT

YEAR	PER CENT PREGNANT	WEANING WEIGHT IN POUNDS
1953	44	350
1954	55	415
1955	82	432
1956	86	428
1957	88	431
1958	88	422
1959	92	406
1960 to 1964	94	508

1. It avoids the cost of wintering cows which are nonpregnant.
2. The number of replacement heifers needed to replace open cows is known before yearling heifers are sold.
3. Packer buyers will pay a premium for cows palpated and known to be open. This increase in sale price frequently is enough to pay for all or most of the costs for palpating the cows.

An alternative system is to cull all cows which fail to freshen during the calving season. This method has the advantage of giving nonpregnant cows an opportunity to gain weight, and cows sometimes sell for a higher price during the spring than during the fall. These advantages generally are outweighed by those listed above for palpating cows in the fall, however.

Some examples of the physical response to culling open cows are shown in Tables 67, 68, 69, and 70. Unfortunately, the com-

parisons are confounded with time and management practices and do not permit contemporary comparison of herds which were culled and those which were not. The weight data shown in Tables 67 and 68 clearly indicate, however, that the improvement in reproduction which occurred after the policy of culling non-pregnant cows was initiated could not be explained on the basis

TABLE 68.—PREGNANCY RATE IN STATION HERD BEFORE (1951-1959) AND AFTER (1960-1964) ESTABLISHING THE POLICY OF CULLING NON-PREGNANT FEMALES

Group	Pregnancy Per Cent		Weaning Weight	
	1951-1959	1960-1964	1951-1959	1960-1964
Angus (A)	76	92	323	333
Brahman (B)	50	78	330	330
A x B	73	93	422	358
Average	66	88	358	350

of the nutritional status of the herd. In Table 67, most of the improvement in reproduction occurred before weaning weights increased. In Table 68, weaning weights before the policy of culling open cows was established were slightly better than afterward.

While the evidence shown in the tables for improvement in

TABLE 69.—IMPROVEMENT IN REPRODUCTION IN INSTITUTIONAL HERD CULLED FOR REPRODUCTIVE FAILURE

Year	Per Cent Pregnant
1958	32
1959	53
1960	53
1961	71
1962	67
1963	83

TABLE 70. —PREGNANCY RATE IN PRIVATELY OWNED COMMERCIAL COWS IN NORTH FLORIDA*

YEAR	PREGNANCY PER CENT
1956	64
1957	73
1958	92

*No culling had been practiced prior to 1956. Thus, pregnancy rate in 1963 represents that for unculled herd. In 1956, part of the nonpregnant cows were culled and in 1957 all nonpregnant cows were culled. (From Florida *Agricultural Experiment Station unpublished data by Dr. A. C. Warnick).*

TABLE 71.—ESTIMATED EFFECT OF CULLING NONPREGNANT COWS ON BEEF PRODUCTION AND ECONOMIC RETURNS WHEN REPRODUCTION RATE REMAINS CONSTANT*

	CULLING POLICY					
	NO CULLING			NONPREGNANT COWS CULLED		
Age Distribution						
Calves		99			207	
Yearlings		97			202	
2 yr.		95			198	
3		93			146	
4		91			107	
5		89			79	
6		87			58	
7		86			43	
8		84			31	
9		82			23	
10		81			17	
11		79			12	
Animals Sold	No.	Wt. (lbs.)	Value ($)	No.	Wt. (lbs.)	Value ($)
Steer calves	274	117,820	23,564	245	105,350	21,070
Heifer calves	176	70,400	11,968	38	15,200	2,584
Open cows	0	—	—	175	166,250	24,938
Old cows	79	71,100	8,532	12	10,800	1,296
Total	529	259,320	44,064	470	297,600	49,888

productive efficiency can be improved where it is low. Reproduction in Florida beef cattle is the lowest of any state in the Union. Its improvement would contribute more to increased economy of production than any other single item. It goes without saying that a satisfactory nutritional program is essential for a high level of reproduction. There are numerous cows in Florida, however, that will not reproduce regularly on any nutritional level. Culling cows for reproductive failure is essential if Florida is to correct low reproductive efficiency in any reasonable period of time. As shown in Table 71, there is a distinct economic advantage in culling open cows, even if the practice did not improve pregnancy rate. More important, however, is the improved reproductive efficiency that invariably occurs when cows are culled for reproductive failure.

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W. L. REYNOLDS

Breeds and Reproduction

A factor of primary importance in a beef cattle operation is the reproductive rate which is reflected in the number of calves weaned and the pounds of calf weaned per cow placed in the breeding herd. The pounds of calf weaned per animal unit exposed depends upon the reproductive rate, survival rate, and age and growth rate of calf. Calves uniform in age, weight, and grade demand a higher price per pound when sold on the market. Cows becoming pregnant in a short breeding season have a shorter calving season and produce calves of a uniform age and weight. Calves are marketed at a heavier weight since they

TABLE 72.—REPRODUCTION RATES REPORTED IN NATIONWIDE SURVEY

BREED	COWS WITH LIVE CALVES (%)	COWS WITH WEANED CALVES (%)
Angus	87	63
Hereford	83	70
Polled Hereford	76	59
All breeds	80	63

Source: Ensminger *et al.* (1955)

are older when removed from the cow. Differences in calving and weaning percentages of different breeds of beef cattle of European origin were found in a survey by Ensminger *et al.* (1955). Differences in calving and weaning percentages which represent death loss of calves were high (Table 72). Wiltbank (1957) showed that Angus and Hereford cows had higher pregnancy rates than Shorthorn cows in Virginia (Table 73).

A survey by Kincaid (1957) compared the reproductive rate of over 11,000 cows in breeding herds at the Agricultural Experiment Stations in the Southeastern United States and showed a 79 per cent calving rate for cows of European breed origin and a 78 per cent calving rate for cows of Zebu or Zebu-European breed origin (Table 74). Some variation was noted in calving per cent within the classes. Most studies show that cows of European breeding have higher reproductive rates than cattle of Zebu origin. Crossbreds between the European breeds have slightly higher pregnancy rates than either of the two breeds involved (Table 75). Less very early embryonic loss of the fetus occurs for crossbred than for straightbred fetuses. Higher pregnancy rates were generally obtained for first cross European-Zebu females than for either of the parent breeds. The pregnancy rate of breeds of cows derived from Zebu-European origin

TABLE 73.—PREGNANCY RATE IN BRITISH BREEDS AT U.S.D.A. FRONT ROYAL, VIRGINIA (1956-1957)

BREED	NO. COWS	PREGNANT (%)
Angus	334	89
Hereford	276	87
Shorthorn	340	82

Source: Wiltbank (1957)

TABLE 74.—REPRODUCTION PERFORMANCE OF BEEF COWS AT ALL EXPERIMENT STATIONS IN SOUTHEASTERN UNITED STATES

BREED	NO. FEMALES	COWS CALVING (%)	COWS WEANED CALVES (%)
British			
Angus	2,314	80	74
Hereford	4,915	80	74
Shorthorn	925	75	61
British x British	822	80	72
Total British	8,851	79	73
Zebu:			
Purebred Brahman	430	73	61
Brangus	813	75	69
Santa Gertrudis	227	62	[illegible]
Afric. x Angus	315	73	72
Brahman crosses	2,427	77	72
Total Zebu Blood	4,213	74	72

Source: Kincaid (1957)

TABLE 75.—AVERAGE PREGNANCY RATE OF STRAIGHTBRED AND FIRST CROSS COWS AT LOUISIANA STATE UNIVERSITY, BATON ROUGE, LOUISIANA (1952-1962)

BREED OF DAM	NO. OF MATINGS	COWS PREGNANT (%)
Angus	354	57
Brahman	343	63
Brangus	303	64
Hereford	328	57
Total Straightbred Dams	1,328	60
TYPE OF FIRST CROSS DAM		
British-British	188	74
Brahman-British	215	84
Brangus-British	218	78
Brahman-Brangus	86	79
Total First Cross Dams	707	80

Source: Schilling (1964)

has been low. This is clearly indicated where Brangus and Brahman-Angus first cross cows have been mated to Brangus and Charolais bulls (Table 76).

The calving and weaning performance of beef cattle is affected by various factors. Genetic and environmental factors both influence the reproductive rates.

FACTORS AFFECTING REPRODUCTIVE PERFORMANCE

AGE AT PUBERTY

There is a considerable difference in breeds in the age at which the female shows heat and ovulates a fertile ovum or egg for the first time. The age of puberty is of utmost importance where heifers are bred as yearlings to calve at two years of age.

Angus have repeatedly shown first heat at a younger age

TABLE 76.—COMPARISON OF BRANGUS AND FIRST CROSS BRAHMAN x ANGUS COWS BRED TO CHAROLAIS AND BRANGUS BULLS AT THE IBERIA LIVESTOCK EXPERIMENT STATION JEANERETTE, LOUISIANA (1964-65)

BREED OF COW	CHAROLAIS BULLS % PREGNANT	BRANGUS BULLS % PREGNANT
Brangus	76	73
First Cross Brahman x Angus	96	93

than any other breeds (Tables 77 and 78). Herefords and Shorthorn have been somewhat intermediate and erratic in the age at puberty. Crossbreds of European origin reach puberty at a younger age than the average age at puberty of the two parent breeds involved in the cross, showing this trait is heterotic in

TABLE 77.—AGE AND WEIGHT AT PUBERTY OF STRAIGHTBRED AND CROSSBRED HEIFERS AT FORT ROBINSON BEEF CATTLE RESEARCH STATION, CRAWFORD, NEBRASKA 1960-61.

BREED	AGE AT PUBERTY (DAYS)	WEIGHT AT PUBERTY (LBS.)
Straightbred		
Angus	394	518
Hereford	464	594
Shorthorn	411	500
Avg. for straightbreds	423	538
First Crosses		
Angus x Hereford	382	524
Hereford x Angus	403	567
Angus x Shorthorn	372	518
Shorthorn x Angus	360	500
Hereford x Shorthorn	367	542
Shorthorn x Hereford	378	505
Avg. for First Crosses	377	526

TABLE 78.—AGE AT PUBERTY OF CROSSBRED AND STRAIGHTBRED HEIFERS AT LOUISIANA STATE UNIVERSITY, BATON ROUGE, LOUISIANA

BREED	NUMBER	AVERAGE AGE AT FIRST HEAT (DAYS)
Straightbreds		
Angus	12	387
Brahman	10	538
Brangus	12	505
Hereford	19	471
Single Crosses		
British x British	20	373
British x Zebu	34	422
Brahman x Brangus	3	482
Charolais x British	11	406
Charolais x Zebu	5	425
Back-Crosses		
British — no Brahman	37	425
¾ British, ¼ Brahman	36	405
¾ Brahman, ¼ British	9	532
¾ Charolais, ¼ British	29	435
¾ Charolais, ¼ Brahman	11	420

Source: Franke and England (1965)

nature. Brahman and breeds of European-Brahman origin were consistently later than the European breeds in reaching puberty (Table 79). About 10 per cent of the Brahman and Brangus heifers had not shown puberty by 27 months of age. First cross Zebu-European breed heifers have a faster growth rate which may partially account for the younger age at puberty in crossbred heifers. The differences in age at puberty also occur in heifers placed on a high nutritional plane. A recent study at the Iberia Livestock Experimental Station showed a higher percent-

TABLE 79.—AGE AND WEIGHT AT PUBERTY OF STRAIGHTBRED AND CROSSBRED BEEF CATTLE AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA.

ITEM	NO.	AGE AT PUBERTY (DAYS)	AVG. MONTHS	WEIGHT AT PUBERTY (LBS.)
Angus	26	433	14.4	536
Brahman	12	816	27.2	706
Brahman x Angus	29	460	15.3	666
Brangus	102	531	17.7	639
Afric-Angus	35	542	18.1	623

Source: Reynolds (1963a).

TABLE 80.—PERCENTAGE OF ZEBU-EUROPEAN CROSSBRED HEIFERS SHOWING HEAT IN A 168-DAY FEEDING PERIOD AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1961-1963)

BREED OF SIRE	BREED OF DAM	NO.	SHOWING HEAT (%)
Angus	Zebu Cross	40	62
Brahman	Zebu Cross	28	3
Sindhi	Zebu Cross	17	17

TABLE 81.—REPRODUCTIVE PERFORMANCE OF ANGUS, BRAHMAN, AND BRAHMAN x ANGUS FIRST CROSS HEIFERS EXPOSED AT TWO YEARS OF AGE AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1965)

BREED	NO. EXPOSED	NO. IN HEAT	IN HEAT (%)	PER CENT PREGNANT
Angus	14	14	100	79
Brahman	14	0	0	0
Brahman x Angus or Angus x Brahman F_1	16	16	100	69

age of crossbred calves sired by Angus bulls reached puberty at a younger age than crossbred calves sired by Brahman or Sindhi bulls (Zebu type cattle imported from India) when placed on full feed for 168 days after weaning (Table 80). The age at puberty can have an extremely important effect on reproductive rate where heifers are bred at two years of age to calve at three years of age in a 75-day breeding season as shown in Table 81.

THE EFFECT OF WEIGHT ON THE SUBSEQUENT REPRODUCTIVE PERFORMANCE OF TWO-YEAR-OLD HEIFERS

A difference in the effect of growth rate on the subsequent pregnancy rate for heifers of Africander-Angus and Brangus breeding at two years of age has been shown. The calves heavier

TABLE 82.—EFFECT OF WEANING WEIGHT ON SUBSEQUENT REPRODUCTIVE PERFORMANCE OF HEIFERS AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

WEANING WEIGHT CLASS	AFRIC-ANGUS CALVING (%)	BRANGUS CALVING (%)
Under 350 lb.	78	60
350-399	73	61
400-449	80	75
450-499	91	84
500-599	100	80

Source: Reynolds *et al.*, (1963b).

at weaning had higher subsequent calving percentages at three years of age than calves in the lighter weight categories (Table 82). The weight at two years of age also influenced the subsequent reproductive rate (Table 83). Generally as weight increased calving rate increased proportionately. Inherent growth rate has an important bearing on subsequent reproductive performance.

LACTATION STATUS

Nursing of a calf has a different effect on the reproductive rate of Brahman cows than on cows of the European breeds. Nonlactating cows of Zebu breeding generally have higher reproductive rates than lactating cows. Among the European breeds, cows nursing calves have higher calving percentages than non-

TABLE 83.—EFFECT OF WEIGHT AT TWO YEARS OF AGE ON SUBSEQUENT REPRODUCTIVE PERFORMANCE OF HEIFERS AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

WEIGHT CLASS	AFRIC-ANGUS CALVING (%)	BRANGUS CALVING (%)
Less than 550 lb.	—	50
550-599	43	70
600-699	73	78
700-799	88	81
800-899	94	75

Source: Reynolds, *et al.*, (1963b).

TABLE 84.—CONCEPTION RATE BY BREED OF DAM WITHIN LACTATION STATUS AT LOUISIANA STATE UNIVERSITY, BATON ROUGE, LOUISIANA

	NONLACTATING COWS		LACTATING COWS	
BREED OF DAM	NO. COWS	CONCEPTION RATE (%)	NO. COWS	CONCEPTION RATE (%)
Angus	103	54.4	251	62.2
Brahman	95	75.8	248	59.3
Brangus	80	62.5	223	70.0
Hereford	112	49.1	216	61.1
British x Brahman	107	53.5	362	84.2
British x British	33	50.4	106	76.3

Source: England *et al.*, 1963.

TABLE 85.—EFFECT OF LACTATION STATUS, AGE AT BREEDING ON THE PREGNANCY RATE AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1960-62)

	AGE AT BREEDING (%)		
	2 YRS.	3 YRS.	4 YRS. AND OLDER
Angus			
Nonlactating	78	50	50
Lactating	—	80	86
Africander-Angus			
Nonlactating	85	74	100*
Lactating	—	83	84
Brangus			
Nonlactating	72	65	78
Lactating	—	50	78
Brahman			
Nonlactating	57	90	75
Lactating	—	50	75

*Small numbers

lactating cows (Tables 84 and 85). The magnitude of differences in calving percentages of nonlactating cows and cows nursing a calf of European breeding show all nonlactating cows not pregnant should be culled from the herd. Lactation exerts a more adverse effect on the reproductive performance of young cows than older cows. The greatest reduction in pregnancy rate due to lactation occurs in the three-year-old cow. Pregnancy records of Brahman and Brangus cows kept in Louisiana (Table 85) show the same pregnancy rate for lactating and dry cows older than 4 years of age.

INTERVAL FROM CALVING TO FIRST HEAT

There are differences between breeds in the number of days required from calving to the first subsequent heat period. The average interval from calving to first heat at the Iberia Livestock Station for Angus was 63 days, for Brahman 79, Brangus 74, and Africander-Angus 80 days. These data indicate a 16-day difference between the Angus and the Brahman.

More Brahman and Zebu-cross cows are open at the end of the breeding season because of lack of heat than for any other reason. Most Angus cows in average condition show heat during the breeding period. Cows of all breeds will not show heat if they are in thin flesh.

PREGNANCY RATE PER SERVICE

TABLE 86.—PREGNANCY RATE AT EACH SERVICE FOR COWS AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1960-63)

BREED GROUP	1ST SERVICE (%)	2ND SERVICE (%)	3RD OR 4TH SERVICE (%)
Angus	60	53	18
Africander-Angus	69	68	40
Brahman	49	41	45
Brangus	53	49	40
Brahman x Angus F_1	78	72	25

season. Sixty per cent of the Angus, Africander-Angus, and Brahman x Angus first cross cows which settled became pregnant in the first 21 days of the season (Table 87). Less than 50 per cent of the Brahman and Brangus cows becoming pregnant did so in the first 21 days. Calves born early in the calving season have considerably greater monetary value per head than late calves even where the same growth rate is present. Where all calves are weaned on the same date, a calf gaining at 1.5 pounds per day is 90 pounds heavier than a calf with the same rate of gain but 60 days younger in age at weaning. A low subsequent pregnancy rate the following year for young cows becoming pregnant in the final 33 days of the breeding season is a common occurrence. The stress of lactation and insufficient supply of available nutrients are causes of this condition. Most of the non-pregnancies occur because of lack of estrus in the three and four-year-old lactating cows.

Table 88 shows breeds of cows which were similar for preg-

TABLE 87.—DISTRIBUTION OF PREGNANCIES BY PERIODS IN A 75-DAY BREEDING SEASON AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1960-63)

BREED	PREG. IN 0-21 DAYS (%)	PREG. IN 21-42 DAYS (%)	PREG. IN 43-63 DAYS (%)	PREG. IN 63-75 DAYS (%)
Angus	64	28	7	1
Brahman	38	22	28	12
Brangus	49	29	8	4
Africander-Angus	61	21	15	3
Brahman x Angus F_1	70	18	10	2
Avg. % Preg. per period	55	25	16	4

nancy and other performance traits grouped into two classifications. Angus and Africander-Angus cows comprise Group I while Brahman and Brangus cows comprise Group II. The effect of age, breed, and time of pregnancy on pregnancy rate the following year are shown. The chances of pregnancy were lower the following year for young cows becoming pregnant late in the breeding season. This applies to both breed groups. Adequate reproductive rates are shown for mature cows of all breeds where cows conceived in the first 42 days of the breeding season.

TABLE 88.—EFFECT OF TIME OF PREGNANCY ON THE SUBSEQUENT PREGNANCY RATE THE FOLLOWING YEAR AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA 1960-1963

	Time of Pregnancy			
	1st 42 days		Final 33 days	
Breed Group	No. Exposed	Pregnant (%)	No. Exposed	Pregnant (%)
3 & 4 years of age				
Angus & Afric-Angus	65	85	18	33
Brahman & Brangus	80	74	39	43
Total	145	79	57	40
5 years or more of age				
Angus & Afric-Angus	166	88	21	11
Brahman & Brangus	160	87	57	68
Total	326	87	78	69

It is imperative that two-year-old heifers become pregnant in a short period of time to allow ample time from calving to first heat for the lactating three-year-old heifer. A profitable practice to overcome the longer interval from calving to first heat in first-calf heifers would be to provide two-year-old heifers with excellent pasture and expose them to bulls about 20 to 30 days before the regular breeding season begins. Also, bulls should be removed about 20 to 30 days before the breeding season ends.

TABLE 89.—EFFECT OF BREED OF SIRE AND BREED OF DAM ON CALVING RATE AT THE RANGE CATTLE STATION, ONA, FLORIDA (1944-48)

BREED OF DAM	BREED OF SIRE		
	SHORTHORN	BRAHMAN	X-BRED
	CALVING (%)	CALVING (%)	CALVING (%)
Grade cows of mixed breeding	80	73	65
Brahman	78	72	—
Shorthorn x Brahman F_1	88	84	—
¾ Brahman, ¼ Shorthorn	95	72	—

Source: Reynolds (1960)

often Zebu-cross bulls have been mated *inter se* to Zebu-cross dams. Nearly all information to date shows the lowered calving rate for breeding programs involving *inter se* matings. This effect may be due to the inability of the genes of Zebu and European breeding to recombine, thus causing partial sterility. Higher pregnancy rates have been found for cows mated to European breed bulls than for cows mated to Brahman bulls (Table 90). Observations both at the Iberia Livestock Station and at Louisiana State University have shown the preferential mating effect of Brahman bulls to Brahman or Brangus cows rather than Angus cows. An occasional individual Brahman bull has refused to mate with Angus cows. Brahman bulls, as is commonly known, usually do not show as much libido and excitement as Angus bulls. The difference in pregnancy rate of cows mated to Angus bulls and to Brahman bulls (Table 91) cannot be all explained on the basis of preferential mating. About equal numbers of

TABLE 90.—CALVING PERCENTAGE OF COWS MATED TO BULLS OF DIFFERENT BREEDS AT LOUISIANA STATE UNIVERSITY, BATON ROUGE, LOUISIANA

BREED OF DAM	BREED OF BULL			
	ANGUS	BRAHMAN	BRANGUS	HEREFORD
	CALVING (%)	CALVING (%)	CALVING (%)	CALVING (%)
Angus	75	46	54	62
Brahman	75	68	54	72
Brangus	80	65	74	66
Hereford	63	48	54	67

Source: Chapman and England (1965)

TABLE 91.—EFFECT OF BREED OF SIRE ON THE PREGNANCY RATE OF COWS OF DIFFERENT BREEDS AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

BREED OF DAM	BREED OF BULL			
	ANGUS	BRAHMAN	AFRIC-ANG.	BRANGUS
	CALVING (%)	CALVING (%)	CALVING (%)	CALVING (%)
Angus	89	79	—	—
Brahman	70	70	—	—
Africander-Angus	88	70	90	—
Brangus	73	65	—	75

Source: Reynolds *et al.*, 1965a.

cows with Angus and Brahman bulls were marked with grease paint pigment mixtures when bulls were painted and cows observed for heat daily. Cows exposed to Brahman bulls, however, had lower conception rates per service than cows exposed to Angus bulls. Brahman bulls thus mount but either fail to ejaculate or supply semen of lower quality. Site of deposition of semen may also be a factor involved. Restricting the size of mixed breeding herds to allow fewer cows per bull or placing bulls with only

TABLE 92.—PERCENTAGE OF TWO-YEAR-OLD HEIFERS REQUIRING ASSISTANCE AT CALVING AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA (1965)

BREED OF DAM	BREED OF BULL			
	ANGUS		BRAHMAN	
	NO.	ASSISTANCE REQUIRED (%)	NO.	ASSISTANCE REQUIRED (%)
Angus	7	28	9	78
Brahman x Angus F_1	9	22	11	27

one breed of cow may have merit in eliminating the preferential mating of the Brahman. Frequent changing of bulls in the breeding herd has also been suggested. Considerable attention needs to be devoted to selection of vigorous bulls with high levels of fertility.

The breed of sire has effect on calving difficulties as shown in Table 92. Yearling heifers of Angus and Brahman x Angus first cross breeding have been bred to Angus and Brahman bulls. Seventy-eight per cent of the Angus heifers bred to Brahman bulls required assistance at calving compared to twenty-eight per cent

of the Angus heifers bred to Angus bulls. Level of nutrition had very little effect on the incidence of calving difficulties in either breed group (Table 92). Breed of sire had little effect on percentage of crossbred heifers requiring assistance. Wiltbank (1964) has shown that higher percentages of calves from some

TABLE 93.—GESTATION LENGTH BY DIFFERENT BREEDS OF COWS MATED TO ANGUS AND BRAHMAN BULLS AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

	Breed of Sire					
	Angus		Brahman		Afric.-Ang. or Brangus	
Breed of Dam	No.	Days	No.	Days	No.	Days
Angus	68	280	24	287		
Brahman	25	284	45	291		
Afric-Angus	26	282	15	290	60	288
Brangus	22	283	24	292	106	286

Source: Reynolds *et al.*, 1965a.

bulls require assistance at calving than from other bulls. Bulls either small at birth themselves or which have a history of siring small calves at birth should be used on first exposure heifers. Brahman cows are practically free of calving difficulties since very few Brahman or European-Brahman crossbred calves require assistance at calving.

EFFECT OF GESTATION LENGTH AND BIRTH WEIGHT OF CALVES

There are considerable differences in the gestation length of cows of different breeds. The gestation length of Angus, Brahman, Africander-Angus, and Brangus cows has been found to be 280, 291, 288, and 286 days respectively (Table 93). Breed of

TABLE 94.—EFFECT OF BREED OF DAM AND BREED OF SIRE ON BIRTH WEIGHT OF CALVES AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

	Breed of Sire		
Breed of Dam	Angus	Brahman	Afric.-Ang. or Brangus
Angus	58	72	
Brahman	61	58	
Africander-Angus	61	77	67
Brangus	59	72	62

Source: Reynolds *et al.*, 1965b.

sire influences both gestation length and birth weight. Angus cows bred to Brahman bulls have a longer gestation length by seven days than Angus cows mated to Angus bulls. Brahman calves and Angus calves were lighter weight at birth than crossbred calves (Table 94). Breed of sire also influences the birth

TABLE 95.—INFLUENCE OF PERCENTAGE OF BRAHMAN BREEDING IN CALVES ON BIRTH WEIGHT AT THE RANGE CATTLE EXPERIMENT STATION, ONA, FLORIDA

BRAHMAN IN CALF (%)	BIRTH WEIGHT	DEV. FROM MEAN (LBS.)
50.0	68.0	3.2
62.5	67.9	2.1
75.0	68.4	1.9
87.5	63.2	–3.9
Grade	64.8	–0.7

Source: Reynolds (1960)

weight of calves. Calves born to cows bred to Brahman bulls are consistently larger at birth than calves born to cows bred to Angus bulls. The increased birth weight of crossbred calves was probably due to the increased gestation length. For each day increase in gestation length calves increased 0.65 lb. in birth weight. Vigorous calves medium in size at birth are more desirable than large calves because of calving difficulties. Information from Florida would indicate the size of the crossbred calf born is directly proportional to the percentage of Brahman breeding of the fetus (Table 95).

SURVIVAL RATE OF CALVES

Most death losses occur in calves in the first week. Nearly all studies show an advantage in survival rate of the crossbred over the straightbred calves (Table 96). The increased vigor of the crossbred calf at birth no doubt accounts for the higher survival rate (Table 97). At the Iberia Livestock Station (Table 98), the highest death loss among the straightbreds have been the Brahman calves. Causes of death have been weak calves, exposure to weather, lack of inclination or inability to nurse, large teats, and pneumonia. Shifting the calving season from the cold winter months to the spring may reduce the death loss of calves.

TABLE 96.—PER CENT CALF DEATH LOSS AT THE RANGE CATTLE STATION, ONA, FLORIDA (1944-58)

BREED GROUP	DEATH LOSSES (%)
Straightbred	
Brahman	4.1
Shorthorn	3.2
Grade Shorthorn	1.0
Crossbred Calves	
Brahman x Shorthorn F_1	1.3
Brahman x Shorthorn Backcross	1.3
Others	0.4

Source: Reynolds (1960)

TABLE 97.—DEATH LOSS OF CALVES FROM BIRTH TO WEANING AT EVERGLADES EXPERIMENT STATION, BELLE GLADE, FLORIDA (1956-59)

BREED	DEATH LOSS (%)
Straightbred Calves	
Angus	7
Brahman	22
Devon	24
Crossbred Calves	
Angus x Brahman First Cross	5
Devon x Brahman First Cross	13
Angus x Brahman (Other Crosses)	5
Brahman x Devon (Other Crosses)	9

Source: Cunha *et al.*, 1963

TABLE 98.—DEATH LOSS OF CALVES FROM BIRTH TO WEANING AT THE IBERIA LIVESTOCK EXPERIMENT STATION, JEANERETTE, LOUISIANA

BREED OF CALF	DEATH LOSS (%)
Straightbred Calves	
Angus	7.0
Brahman	23.2
Africander-Angus	6.2
Brangus	13.6
Crossbred Calves	
Angus x Brahman	3.0
Angus x Africander-Angus	4.2
Angus x Brangus	2.3
Brahman x Angus	2.3
Brahman x Africander-Angus	10.3
Brahman x Brangus	6.2

Source: Reynolds *et al.*, 1965a

SUMMARY

These data show that differences in reproductive rates of breeds have been noted. Generally speaking, cattle of European breeds have higher reproductive rates than Zebu cattle. Most studies, however, have shown the European-Zebu crosses to be higher than the straightbred European breeds in reproductive performance in the Southeastern portion of the United States. The reproductive rate of matings of Zebu-European crossbreds to Zebu-European crossbreds have been consistently lower than matings of Zebu-European crossbreds to a straightbred parent. The influence of age at puberty, size at weaning and at two years of age, lactation status, interval from calving to first heat, pregnancy rate per service, the effect of time of pregnancy on subsequent reproductive performance, breed of sire, calving difficulties, calf survival rate, gestation length, and birth weight on reproductive performance have been discussed. Most Brahman and Zebu-cross cows are nonpregnant at the end of the breeding season because of lack of estrus. Most Angus cows show estrus during the breeding season. Improving the overall nutritional level of cows will cause larger numbers of cows to show estrus and improve the conception rate at each service. Culling of open cows will improve the reproductive rate of cows of the European breeds and all cows over 4 years of age at breeding. Culling of unthrifty calves at weaning and heifers at two years of age will also improve the reproductive rates.

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A. C. WARNICK

Reproduction of Brahmans in Florida

Since the selection of Brahman cattle for productive beef traits including reproduction has been practiced for only a short time compared to the European breeds, it is not surprising that there may be differences in reproductive behavior. It is not the purpose of this report to compare the European and Brahman cattle in reproductive traits, but to give the results of a two-year study of reproduction in four cooperators' herds in Florida and in Brahman heifers maintained at the Physiology Unit at Gainesville, Florida.

AGE AT PUBERTY

The age at puberty or first heat is important since all females should be showing estrus and ovulating when the breeding season begins in order to have an early and uniform calving period. There is also the possibility that occurrence of puberty at a young age may enhance reproduction, as occurs in swine (Warnick *et al.*, 1951). The ovaries of yearling Brahman heifers were palpated at monthly intervals on three ranches to determine the time of first corpus luteum, which is an index of first heat or puberty. There is some error in detecting the corpus luteum, depending on stage of the cycle, yet monthly palpation is the most efficient way to obtain data on large numbers at different locations. The average age at puberty (first corpus luteum) was 19.8 months (Table 99) with a range of 14 to 26 months (Plasse, *et al.*, 1965A). In one herd there was a −.46 correlation between 205-day weight and age at first corpus luteum, indicating

TABLE 99.—AGE AT PUBERTY* IN BRAHMAN HEIFERS

RANCH	NO. OF FEMALES	AVG. MONTHS	RANGE IN MONTHS	CORRELATION 205 DAY WT. AND AGE AT PUBERTY
A	41	19.4	16-26	–.46
B	33	18.9	14-24	
C	9	21.3	21-33	
Total	83	19.8	14-26	

*Time of first corpus luteum on ovary detected by monthly palpation.

the heavier, growthier heifers began estrus at a younger age. It was observed that more heifers had their first corpus luteum in the spring following their second winter. Also, it is possible that the presence of the bull at the beginning of the breeding season stimulated the presence of the corpus luteum.

ESTRUS AND OVULATION IN BRAHMAN HEIFERS

A group of 53 two-year-old heifers was checked for estrus and ovulation for one year by using vasectomized bulls painted on the brisket to detect estrus, and palpation of the ovaries at weekly intervals to detect the corpus luteum (Plasse, *et al.*, 1965B). The percentage of all heat periods unaccompanied by ovulation was 5.9, with a higher percentage occurring in the summer season (Table 100). Also, 26.3 per cent of the ovulations were not accompanied by estrus, with the highest number occur-

TABLE 100.—EFFECT OF SEASON ON ESTRUS AND OVULATION IN 53 BRAHMAN HEIFERS

CRITERIA	SUMMER SEASON 3/20/62 TO 9/19/62		WINTER SEASON 9/20/62 TO 3/19/63	
	No.	%	No.	%
Estrus	343	53.2	302	46.8
Ovulation	400	48.6	423	51.4
No. estrus without ovulation*	29	76.3	9	23.7
No. ovulation without estrus*	87	40.3	129	59.7

*Differences between two seasons are statistically significant.

TABLE 101.—LENGTH OF ESTROUS CYCLE IN BRAHMAN HEIFERS

CRITERIA	NO. OBSERVATIONS	AVERAGE (DAYS)	MODE (DAYS)	RANGE (DAYS)
Length Estrous Cycle	592	27.6	20	6-256
% cycles 14 to 28 days	76			
% cycles 17 to 23 days	67			
% cycles under 17 days	3			
% cycles over 23 days	30			

ring in the winter season. This would suggest that cooler temperatures or other climatic factors in the winter season inhibit expression of estrus since the nutritional level was the same throughout the year. The bulls were continuously with the heifers, so it is unlikely that the failure was due to bull differences.

The average length of the estrous cycle (interval between heat periods) for 592 observations in these heifers was 27.6 days (Table 101) with the largest number of cycles being 20 days. There was a large amount of variation with many intervals being grouped around 40 and 60 days, indicating ovulation was occurring on a 20-day cycle, but heat was not being detected by the bull.

The length of heat and time of ovulation was studied in 35 heifers during the four seasons of the year (Table 102). Heifers were checked at two-hour intervals with a bull to determine the beginning and length of heat. The criterion used was the standing for mating of the bull. The average length of heat was 6.7 hours with a range of 2 to 22 hours. There was no statistical

TABLE 102.—LENGTH OF ESTRUS AND TIME OF OVULATION AT DIFFERENT SEASONS IN BRAHMAN HEIFERS

SEASON	NO. HEIFERS	LENGTH OF ESTRUS (HOURS)	RANGE (HOURS)	TIME OVULATION IN RESPECT TO ESTRUS: FROM BEGINNING (HOURS)	FROM END (HOURS)
Spring (May)	10	8.6	2-22	28.1	19.5
Summer (Sept.)	10	5.5	2-12.5	22.6	17.2
Fall (Nov.)	5	5.4	4-6.5	24.7	19.2
Winter (Jan.)	10	6.8	2-16	26.6	19.9
	—	—	—	—	—
Overall total & average	35	6.7	2-22	25.6	18.9

difference in length of heat among the four seasons, although heat periods were slightly longer in the spring. The time of ovulation (rupture of the follicle) was determined by rectal palpation of the ovaries at two-hour intervals beginning at the end of heat and continuing until detection of the ruptured follicle. The average interval from beginning of heat to ovulation was 25.6 hours and from the end of heat was 18.9 hours. These intervals were not affected by seasons of the year.

Fertilization and Embryo Survival Rate

After estrus behavior had been studied for one year, the Brahman heifers were bred at three years of age to fertile Brahman bulls and one half killed three days postbreeding and one half killed 40 days postbreeding. This procedure gives an estimate of fertilization and embryonic survival rate. Twenty-four heifers slaughtered three days postbreeding had 66.7 per cent of the eggs fertilized as shown by cell division, although there was disintegration in some eggs (Table 103). In 20.8 per cent of the heifers no eggs were recovered, so it was not possible to determine fertilization in all heifers. This failure of egg recovery may be due either to technique or an actual deficiency in the egg pick-up mechanism of the oviduct. There were 64 per cent of the heifers with normal embryos at 40 days postbreeding, with 8 per cent having a resorbed or hemorrhagic

TABLE 103.—FERTILIZATION AND EMBRYO SURVIVAL RATE IN BRAHMAN HEIFERS

	No. heifers	Per Cent
3 days postbreeding		
Fertilized egg	16	66.7
Unfertilized egg and ruptured egg with sperm	3	12.5
No egg recovered	5	20.8
Total	24	100.0
40 days postbreeding		
Normal embryos	16	64.0
Hemorrhagic and resorbed embryo	2	8.0
Returned in estrus	7	28.0
Total	25	100.0

embryo. Before 40 days 28 per cent returned in heat and were rebred.

It would appear that early embryonic death was not a major factor in breeding performance of these Brahman heifers, since the percentage with fertilized eggs at three days and percentage with normal embryos at 40 days was similar.

GESTATION LENGTH AND CALVING INTERVAL

Data on the gestation length in Brahman cows is shown in Table 104. The gestation period of cows carrying male fetuses was 1.86 days longer than cows with female fetuses. Also, the

TABLE 104.—GESTATION LENGTH IN BRAHMAN COWS

NO. OBSERVATIONS	AVERAGE (DAYS)	RANGE (DAYS)
1,048	292.8	271-310

Source: Plasse *et al.*, (1965C).

sire of a calf significantly influenced the gestation length of the cow, varying from 286 to 297 days, based on 40 Brahman bulls studied. This would indicate the genetics of the fetus influence gestation length as well as the genetics of the dam.

The calving interval which is measured as the number of days between birth dates of calves was studied from records of four Brahman herds (Table 105). The average calving interval for all cows was 410 days, while it was only 375 for those cows with only consecutive year calving (Plasse *et al.*, 1965D). The averages among the ranches varied from 400 to 424, with ranches having a shorter breeding season also having a shorter calving interval. The interval for cows calving after the breeding season began was 357 days, compared to 392 days for those calving before breeding began, indicating some cows were coming into heat before the breeding season began. The calving interval was 23 days longer for cows calving first at two or three years, compared to calving first at four or five years of age.

The average interval from the beginning of the breeding season to conception was studied in heifers and cows by subtracting a standard gestation length of 293 days from the calving dates (Table 106). This interval was 45 days for cows which had calved at least one month before the breeding season began, compared

TABLE 105.—CALVING INTERVALS IN BRAHMAN COWS

CRITERIA	CALVING INTERVALS No. INTERVALS	AVERAGE (DAYS)
All intervals	2,924	410 (120.7)*
Only consecutive years	2,527	375 (50.2)
Ranch		
1	773	424
2	671	415
3	859	400
4	1,635	400
Calving before breeding season began	1,617	392
Calving after breeding season began	910	357
Calving first at 2 & 3 years of age		421
Calving first at 4 & 5 years of age		398
Age at Calving (years)		
3 to 4		398
5		432
6		420
7 to 10		391
11 to 15		398

*Standard deviation

to 64 days for heifers being bred for the first time. The delay in heifers is possibly due to either delayed puberty or anestrous occurring in the late winter and early spring.

The interval from parturition to conception was calculated for those cows calving after the breeding season began at four ranches (Table 107). There were highly significant differences among the ranches, with the shortest interval being 59 days and the longest 72 days. The average interval of 65 days com-

TABLE 106.—INTERVAL FROM BEGINNING BREEDING SEASON TO CONCEPTION

GROUP	NUMBER	AVERAGE INTERVAL (DAYS)	STANDARD DEVIATION (DAYS)
Heifers	1005	64	54.9
Cows*	1449	45	41.1

*Had calved at least one month before breeding season began.

pared closely with intervals to first estrus of 59 and 63 days in Angus and Hereford cows in Oregon (Warnick, 1955).

SUMMARY

The average age at puberty determined by the presence of a corpus luteum in Brahman heifers on three ranches was 20 months, with a range from 14 to 26 months. The heavier heifers at 205 days of age had a corpus luteum earlier than the smaller heifers.

TABLE 107.—INTERVAL FROM PARTURITION TO CONCEPTION

RANCH	NO. INTERVALS	AVERAGE INTERVAL (DAYS)	STANDARD DEVIATION (DAYS)
1	114	61	30.7
2	132	72	37.2
3	285	71	42.6
4	380	59	36.9
Combined	911	65	38.6

Approximately 26 per cent of the ovulations in 57 heifers were not accompanied by heat, with the greatest number occurring during the winter season from September to March. The average length of the estrous cycle in 57 heifers during one year was 27.6 days, with the largest number of cycles being 20 days. The 27 day average is due to many cycles of approximately 40 and 60 days, indicating ovulation was occurring without heat detection by the bulls. The average length of estrus was 6.7 hours with a range of 2 to 22 hours, in 35 heifers checked for estrus at two-hour intervals with a bull. The time of ovulation from the beginning and from the end of estrus was 25.6 and 18.9 hours, respectively.

The average per cent fertilization rate in 24 heifers bred and slaughtered three days postbreeding was 67 per cent, compared to 64 per cent with normal embryos at 40 days postbreeding in 25 heifers. Thus, early embryonic death does not seem to be a major cause of lowered fertility in heifers bred to fertile bulls for the first time. Gestation length averaged 293 days with a range of 271 to 310 days. Cows with bull calves had a 1.86 day longer interval than those with heifer calves, while there were significant differences due to sire of calf.

The average calving interval was 410 days for all cows compared to 375 days for cows with only consecutive year records. Cows calving after the breeding season began had a shorter calving interval than those calving before the breeding season began. Also, cows calving first at four and five years had shorter calving intervals than those calving first at two and three years of age. The interval from the beginning of breeding season until conception was 19 days shorter in cows that had calved one month before breeding, compared to heifers. The average interval from parturition to conception was 65 days for cows calving after the breeding season began.

The large variability in various reproductive traits between ranches and between individual females would indicate that reproduction rate can be increased by improved management and selection for a higher reproductive rate.

cent conception rate; three-year-old cows, 83 per cent; four- to nine-year-old cows averaged 88 per cent and ten-year and older cows had an 80 per cent conception rate. At the Brooksville Station, conception rate for two-year-olds was 85 per cent; for three-year-olds, 73 per cent; four- to nine-year-olds, 80 per cent, and for ten year and older cows, 74 per cent. Number of cows decline rapidly after ten years of age. This has been due to the

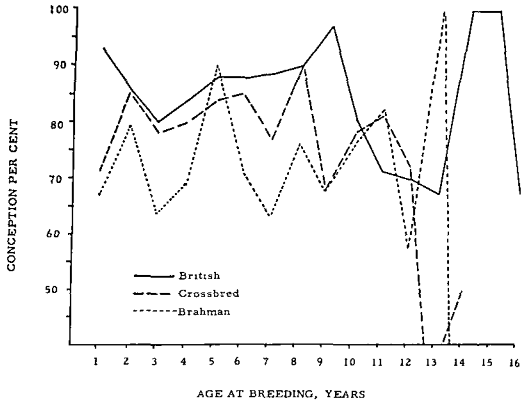

FIGURE 60. *Age and breed interacting on reproductive rate.*

culling of all cows over ten years of age during the past six years. Figure 60 shows the effect of breed and age on reproduction. It shows that British and crossbred cows are fairly steady in reproduction from two to eight years of age, but the Brahmans are very erratic in their breeding behavior.

Age of Bulls

Very little research is available on the effect of age of bulls on reproductive rate. Bowling and co-workers (1940) reported a gradual decrease in breeding efficiency of dairy bulls after six years of age. Higher conception rate in young heifers was noted when they were bred to young bulls (two to four years old)

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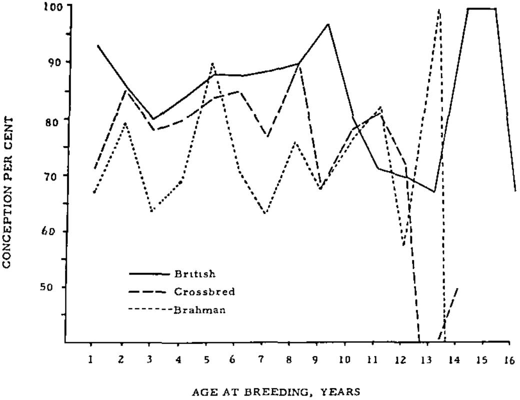

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rather than older bulls. Hilder *et al.* (1944), studying dairy bulls, reported a distinctly higher number of services per conception when heifers were bred to bulls over five years of age than when bred to younger bulls.

Baker and Quesenberry (1944) working with beef cattle, and McCullough and co-workers (1951), using data from dairy herds, reported no significant effect due to age of bulls.

SUMMARY

Researchers studying reproductive performance of cattle have found that age has a significant effect on it. Most studies have reported that the most productive years are from five to ten years of age in cows and that breeding efficiency of bulls decreases after six years of age. Reports also indicate that three-year-old cows have a low conception rate, probably due to stress of nursing their first calf, but at four years of age, the conception rate increases. A survey of two experimental herds in Florida shows that location (environment) and breed also have an effect on production rate. Brahman and British cattle perform differently with crossbreds being intermediate in their performance rate.

It is recommended that cattle producers pay close attention to the ages of their cattle in order to have a high level of reproductive performance. Ranchers should year brand and keep records on their cattle to more easily recognize and remove older and less productive cows. Preferential treatment should be given to young dams shortly before and during their second breeding season to help offset the accompanying stress of nursing their first calf.

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L. S. POPE

Age at First Calving and Performance

The large investment and high costs of feed and labor that go into a beef heifer before she calves the first time make it desirable to get her into production as soon as she is physiologically ready. Normally, beef heifers come into first heat at about 12-14 months of age, depending on breed, environmental conditions, and feed level. At 15 months, most well-fed beef heifers will be cycling regularly and thus can be bred to calve first as two-year-olds. The question is: Is this a desirable and profitable practice, or should first calving be delayed until they attain more maturity?

Obviously, in poorly managed herds, many heifers may be bred too early, and this is altogether undesirable. However, by delaying first calving, we also delay returns and increase the overhead costs per calf weaned during her productive life. Much disagreement exists among producers as to the effects of early calving on lifetime production, and few experiments have been undertaken to study this point.

The growth and development of the heifer up to the time she is bred has an important bearing on the best age for first calving. Many cattlemen hold that the size and development of the heifer are a better yardstick than age alone. Small, late, or undeveloped heifers should be given an extra period of growth to avoid serious trouble at first calving. When heifers are bred early (as yearlings, for example) they should be wintered well to assure good skeletal growth. Winter gains of 1.0 pound per day are desirable. Gains above this are largely soft tissue and fat. When heifers are roughed through the winter so that they

make most of their gain off grass during the summer, they may lack size and development as two-year-olds to avoid serious trouble at calving.

Early Kansas experiments clearly indicated the detrimental effects of early breeding combined with low levels of wintering. At 5 years of age, cows wintered on roughage with no grain, and bred to drop their first calves as two-year-olds, had weaned calves averaging 348 pounds; cows handled in the same manner but bred to calve first as three-year-olds weaned calves that averaged 405 pounds. In this experiment, wintering heifers on roughage only, and calving first at two years of age, reduced the first calf crop by 30 per cent; about one-third of the cows became temporarily sterile. Some of this difficulty with nonbreeders was avoided by feeding grain supplements during the winter months.

Later Oregon experiments, however, showed that heifers which calved first as two-year-olds produced 0.7 more calves during the first 6½ years of life as compared to heifers calving first as three-year-olds. In this experiment, a low level of winter feeding was not as severe on the heifers, although at 4 years of age, cows that had calved first as two-year-olds averaged 100 pounds less in body weight than cows of the same age that calved first as three-year-olds. Likewise, there were a smaller number of calves dropped in the early-calving group at three and four years of age.

In some areas, commercial cattlemen attempt to reduce the heavy strain of lactation so that the heifer may continue to grow and rebreed by vealing the first calf or by early weaning. In purebred herds, the same thing can be accomplished by placing the calf on a nurse cow. Early-calving heifers, relieved of the strain of milk production, usually rebreed earlier than those nursing calves.

Briefly, the disadvantages that often result from breeding heifers to calve first as two-year-olds are:

1. *A heavy death loss among the heifers and their calves* is often experienced at calving time. A large percentage of early-calving heifers require assistance. In an Oklahoma experiment, 28 out of 56 heifers calving at two years of age needed assistance. In another experiment with 237 heifers in a large commercial herd in the Texas Panhandle, an average of 60 per cent of the two-year-olds had to be assisted at calving, and eight

heifers and twenty-nine calves were lost. Together with this high death loss, there is always the danger of permanent injury (posterior paralysis, injury to the genital tract, etc.) which removes the heifer from production. Despite this, one commercial cattleman who operates on a large scale recently stated that although he lost as many as 12 to 15 per cent of the calves and 3 to 5 per cent of the heifers, it was still more profitable to breed heifers as yearlings to calve first at two years of age.

One large Oklahoma commercial herd practices calving heifers at 27 to 30 months of age, with good success. Special attention is given as the heifers approach calving by an experienced herdsman, proper equipment, and a "calving pasture" adjacent to headquarters. Sufficient extra returns (over $70,000) in one year's operation from early calving have made it distinctly profitable in this herd, versus waiting until replacements are three-year-olds. Bulls serving yearling heifers are carefully selected to avoid calving trouble as much as possible.

A few experiments have been conducted on the influence of the birth weight, mature size, and breed of bull on the difficulty experienced by young heifers at calving time. The tests so far may not be the final answer, but there is evidence that within breed, the size, and type of the bull is one of the most important factors contributing to difficulty at calving time. Therefore, in commercial production it is recommended that yearling heifers be bred to a somewhat smaller, more refined type of bull than is used on older heifers or mature cows. In general, less difficulty can be expected from the calves sired by Angus bulls.

In this regard, it should be obvious that the age of the bull is not a factor since the birth weight and size of the calves he sires is genetically the same at any age. A young bull, potentially the sire of big calves, will cause more trouble than an older bull which inherently sires small calves. In selecting the bull to use on young heifers—type, not age, is the more important consideration. However, if the bulls are of the same type, many producers select a young bull for use on the small yearling heifers.

amount of nutrients removed from the body of the dam by the fully developed calf at birth is quite small. The newborn calf is nearly 3/4 water and contains no more protein, fat and mineral than 400-500 pounds of milk. Since lactation places the heaviest strain on the young heifer, a good ration with plenty of protein and energy is essential. Underfed heifers nursing calves may become stunted, fail to rebreed, and wean a small, underdeveloped calf. As mentioned earlier, it may be desirable to place calves from young purebred heifers on a nurse cow so that the heifers can resume normal growth.

3. *Failure to rebreed* the following season is often the case when heifers are bred to calve first as two-year-olds. This results in a high percentage of dry three-year-olds. The demands made on the dam for growth and development of the fetus, plus lactation, take precedence over those for reproduction. Unless feed is plentiful, nature protects the undeveloped heifer in that she fails to conceive the following year. In one experiment, out of 44 heifers that calved as two-year-olds, 10 failed to rebreed the following summer while nursing calves, even though they were fed supplemental feed on grass. Under the same conditions, older cows were observed to rebreed normally.

4. *Early calving retards the development of the heifer.* Heifers bred to calve at an early age require a longer time to reach mature body size. In one experiment, cows that had calved first as two-year-olds averaged 86 pounds lighter at 4 years of age than cows handled under identical conditions, but calving first as three-year-olds. Eventually, this difference in body weight may be largely overcome if feed is ample, and its effect on the lifetime productivity of the beef cow may be minor.

5. *First calves are lighter at weaning* from two-year-old heifers. Generally, this difference under range conditions is about 50 pounds per calf, as compared to three-year-olds, and 75-80 pounds under mature production. As a rule, second calves from early-calving heifers are no heavier at weaning than the first calves from three-year-old heifers.

To study the problem of early calving on lifetime performance, an experiment was undertaken in 1948 at the Ft. Reno Station in central Oklahoma. The effects of age at first age calving were studied within three different levels of winter feeding. The project was started with 15 weaned heifer calves in each of 6 lots. Lots 1 and 2 were designated the "low level" group

and were fed 1.0 pound of cottonseed meal pellets per head daily on dry, native range. Lots 3 and 4, the "medium level" group, were fed 2½ pounds of C.S. meal, while Lots 5 and 6, the "high level" group, received 2.5 pounds of meal and 3.0 pounds of oats per head daily on dry grass each winter. The heifers grazed comparable pastures during the summer and ample forage was available. Heifers of the odd-numbered lots (1, 3, and 5) were bred as yearlings to drop their first calves at two years of age; heifers of the even-numbered lots (2, 4, and 6) were bred as two's to calve at three years of age. Data were obtained over a 14 year period and are summarized in Table 108.

As was expected, the heifers wintered continuously on the "low level" (Lots 1 and 2) lost considerably more body weight during each winter season than those wintered as the medium or high levels. While they made greater summer gains, the heifers of Lot 1, wintered at the low level and bred to calve as two-year-olds, failed to reach the same average body weight at 3½ years of age as their mates on higher feed levels (Lots 3 and 5). After the heifers had been wintered on their respective levels for 3 years, there was 86 pounds difference in the average body weight, over all feed levels, in favor of heifers bred to calve first as three-year-olds. Thus, breeding heifers as yearlings tended to delay their body development, but was more pronounced where winter supplements were limited. This study has permitted the best estimate thus far of the effects of early calving on lifetime usefulness of the beef female. Average results to 14 years of age are shown in Table 108. The survival of beef cows has not been adversely affected by early calving as two-year-olds. Little difference between two- and three-year-old calving is apparent in reasons for removal of females from the test, including those removed as open cows, for failing to calve for two successive years, for disease, or for unsoundness.

Therefore, if the beef heifer is sufficiently well-developed to calve first as a two-year-old, subsequent reproductive processes and her life span in the herd are not adversely affected.

Some measure of the difficulty encountered in calving two-year-old heifers can be seen from Table 108. One heifer was lost at calving, while another was badly injured and sold on the market the following summer. However, at 3½ years of age there was an average of 437 pounds more calf produced by the two-year-olds—an advantage obtained at no extra feed cost.

Some heifers on the low level, calving the first or second time, lost over 300 pounds of body weight from fall to spring. Much of this loss occurred in March and April while they were nursing calves. The summer pasture during the experiment was very good, and ample grass was available. If during these years, spring pastures had been slow to develop due to a drought, substantial economic loss might have occurred among the "low level" cows and calves, with a large number failing to rebreed. In

TABLE 108.—TWO- VS. THREE-YEAR-OLD CALVING ON LIFETIME PERFORMANCE OF RANGE BEEF COWS

AGE AT FIRST CALVING	TWO-YEAR-OLD	THREE-YEAR-OLD
Number females started on test, Fall, 1948	59	60
Number remaining, March, 1962	23	22
Reasons for removal from test		
Open or failing to calve in two successive years.	16	16
Cancer eye	9	6
Spoiled udder	4	5
Crippled	2	2
Disease	1	2
Hardware disease	2	1
Accidental	0	2
Unknown	2	3
Heifers assisted at first calving	28	1
Avg. mature body wt., Fall, 1956 (lb.)	1148	1178
Total number calves weaned	533	482
Number calves weaned per cow year	.80	.71
Total per cent calf crop weaned	86.7	85.2
Average weaning wt., all calves, (lb.) sex corrected	476	485
Average weaning wt., minus two-year-old calf, lb.	482	485
Cow feed cost per cwt. calf weaned, $	10.33	11.34

such a case, the extra feed given to cows of the medium and high level lots might have been worthwhile insurance.

The slight effect on average body weight at maturity is due chiefly to the difference between Lows that calved first as two-year-olds and the High level three-year-olds. Heifers wintered at the High level and calving first as three's were slightly heavier than the average of the other groups.

An extra 51 calves (.09 calf per year) were obtained from the two-year-old calving program. This is about .85 more calf per female started on test than for the three-year-old heifers. It has

amounted to an advantage of nearly 330 pounds calf per cow for the two-year-old first-calving group.

Weaning weights between the two groups were only slightly different and the small difference observed is almost entirely due to the light weight of first calves from two-year-old heifers (nearly 68 pounds lighter than the average of their mature production). Cow cost per 100 pounds of calf weaned, therefore, was reduced by $1.01 for the two-year-old calving regime.

In summary, the data show that heifers handled under practical farm or range conditions may be successfully bred as yearlings (15 to 18 months) to calve at two years of age if:

1. Winter feed is ample to meet the increased demands for growth, gestation, and milk production. Under commercial conditions, heifers should gain at least 1.0 pound/day during the winter period. They should weigh about 600 pounds when bred. Purebred heifers should meet, or exceed, these requirements.
2. Young heifers must be watched closely at calving time; about 50 per cent will need assistance.
3. Heifers must be well-fed while nursing calves.
4. It is best to breed only the larger, well-developed heifers as yearlings, allowing the smaller heifers a chance to grow for another year. Under commercial conditions, a small-type bull should be used on yearling heifers.
5. Calving first as two-year-olds under good care and management does not shorten the life span of the beef female, and may substantially increase total pounds of calf weaned.

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W. C. BURNS

Breeding Season Length and Subsequent Calf Crops

The length of the breeding season ranges from a low of 45 days to year-round breeding in different regions of the United States. However, the average length of breeding seasons in most sections of the country is 90 to 120 days. Due to the many advantages attributed to a short breeding season, more and more people are cutting their breeding season to 60 days, and even less, on first exposure heifers.

Most of the cattle that are going to settle any time during a controlled breeding season will conceive within the first three estrual cycles or 60 days. Baker and Quesenberry (1944) in a study of 4753 cattle in Montana over an 18-year-period, reported a weaning per cent of 81 when cows were bred during a seven-to-eight week period. Rhoad (1944) in a study involving 563 pregnancies in Louisiana, showed that 52 per cent of the cows that gave birth to normal live calves became pregnant within the first 20 days of the preceding breeding season; by 40 days, 80 per cent had become pregnant, and at the end of 60 days, 91 per cent had become pregnant. In another report involving 542 pregnant cows from Louisiana, Reynolds (1964) reported that 55 per cent became pregnant during the first 21 days of the breeding season, by 42 days, 80 per cent, and at the end of 63 days, 96 per cent were pregnant. Data on 331 pregnant Angus cows at the West Central Florida Experiment Station from 1960 through 1965, showed that 46 per cent had become pregnant within the first 20 days of the breeding season, 78 per cent by the end of 40 days, and 90 per cent by 60 days. The breeding season was for 90 days in length during 1960, 1961 and 1962. In 1963 it was 75 days and in 1964 a 60-day breeding season was used.

What happens when the breeding season is shortened from a 90-day to a 60-day season in two years? In 1963, the Angus cattle had a 95 per cent pregnancy rate following a 75-day season and in 1964 an 88 per cent rate following a 60-day season. While there appeared to be a decline in 1964, the difference was no greater than normal year to year variation (Table 109). Indications are that, hereafter, reproduction rate will be as high in a 60-day period as it was when a 90-day season was being used.

TABLE 109.—CALVING DATA FOR ANGUS COWS DURING THE 1964-65 CALVING SEASON

	Breeding Season				Total	
	1963		1964			
Period	No.	Cumulative per cent	No.	Cumulative per cent	No.	Cumulative per cent
1st 20 days	35	57	30	46	65	52
2nd 20 days	53	87	53	82	106	84
3rd 20 days	58	95	63	97	121	96
4th 20 days	61	100	65	100	126	100

TABLE 110.—EFFECT OF AGE OF CALF AND CALF CROP ON POUNDS OF CALF WEANED PER COW BRED

PER CENT CALF CROP	1ST 20 DAYS OF CALVING (AVG. AGE AT WEANING 200 DAYS)	2ND 20 DAYS OF CALVING (AVG. AGE AT WEANING 180 DAYS)	3RD 20 DAYS OF CALVING (AVG. AGE AT WEANING 160 DAYS)	4TH 20 DAYS OF CALVING (AVG. AGE AT WEANING 140 DAYS)
100	450	412	374	336
90	405	371	337	302
80	360	330	299	269
70	315	288	263	235
60	270	247	224	202

Source: Wiltbank (1964)

would be 360 pounds for each calf or a total of 36,000 pounds.

Next, let us look at the effect of age of calf on weaning weight. If calves average 450 pounds at 200 days of age, calves that are 180 days of age will average 412 pounds on the same weaning date. Calves at 160 days of age will average 374 pounds, and 140 day old calves will average 336 pounds in weight.

With these figures in mind, let us take an example of a situation in a typical cow herd (Table 111).

It must be kept in mind that we are assuming the potential pounds of calf weaned per cow bred is 450 pounds. Let us assume an average calf crop of 85 per cent and an 80-day calving season. Fifty-two per cent of the calves would be born in the

TABLE 111.—PERCENTAGE OF CALVES DROPPED AND POUNDS OF CALF WEANED BY 20-DAY CALVING PERIODS IN 100-COW HERD, ASSUMING 80-DAYS CALVING AND 85 PER CENT CALF CROP

	CALVING PERIODS				
	1ST 20 DAYS	2ND 20 DAYS	3RD 20 DAYS	4TH 20 DAYS	SUMMARY FOR 4 PERIODS
Percentage of calves born in period	52	32	12	4	100
Number of calves born in each period	44	27	10	4	85
Av. weaning weight (lbs.)	450	412	374	336	360
Total pounds of calf weaned	19,800	11,124	3,740	1,344	36,008

first 20 days of the calving season, 32 per cent in the second 20 days, 12 per cent in the third 20 days, and 4 per cent in the fourth 20 days. Now consider the pounds of calf weaned per cow. For each 100 cows bred, 44 calves will be dropped the first 20 days of the calving season (52 per cent of the 85 calves born); 27 calves will be dropped the second 20 days; 10 calves the third 20 days; and 4 calves will be dropped in the fourth 20-day period. If the calves are all weaned at the same time the 44 calves dropped during the first 20 days will average 450 pounds for a total of 19,800 pounds of calf and the 27 calves born during the second 20 days will average 412 pounds for a total of 11,124 pounds. The 10 calves born in the third 20-day period would average 374 pounds for a total of 3,740 pounds, and the 4 calves born in the fourth period will average 336 pounds for a total of 1,344 pounds. This would be a total of 36,008 pounds of calf, or approximately 360 pounds of calf per cow bred. If all of the cows had conceived in the first 20 days, we would have 450 pounds per cow bred. In other words, we have lost 90 pounds of calf per cow bred through late breeding and calving.

In order to have the maximum pounds of calf weaned per cow bred, a high percentage of the cows must wean a calf and the calves must be born over a short period of time early in the season. In order to have all cows calve in a short period, they must be bred during a short breeding season. Following is a plan to improve the reproductive performance of a cow herd.

I. Heifers bred for the first time:

A. Breed to calve earlier than the cow herd.

B. Breed for 40 to 60 days, palpate for pregnancy, cull open cows.

C. Have cows gaining in weight at breeding time.

II. Young cows:

A. Separate from older cows.

B. Provide extra feed and have them gaining in weight.

C. Breed for not over 80 days, palpate for pregnancy, cull open cows.

III. Older cows:

A. Have cows gaining in weight at breeding time.

B. Breed for not over 80 days, palpate for pregnancy, cull open cows.

Calving heifers earlier than the regular cow herd provides a

better opportunity for these heifers to be rebred and have an earlier calf the following year. There is a lower pregnancy rate in young cows during the second breeding season and they tend to calve later in the season. This is a result of young cows taking longer to come into heat after calving. Therefore, if a heifer calves late the first year, she is more likely to be open the next year.

SUMMARY

A good calving percentage can be obtained in a 60-day breeding season providing the cattle are under good management. This is possible because all the cows have calved out 30 days prior to putting out the bulls. Under good management, the cattle will all be gaining weight and will have plenty of time to come in heat and be rebred during the 60-day breeding season.

in the cow is somewhat shorter than in most other farm animals, and thus it can be missed more easily. The length of estrus may range from 6 to 30 hours, and the average may be on the order of 14 to 18 hours under different circumstances. Under a system of twice-daily observation for estrus, estrus may begin after a given period of observation and end before the next observation

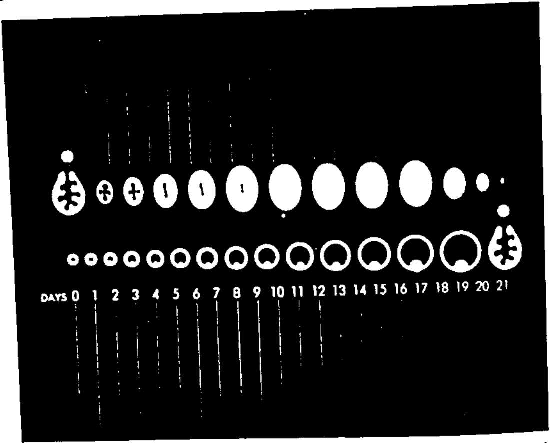

FIGURE 61. Cyclic changes in the corpus luteum (top) and the follicle (bottom) during the normal estrous cycle.

period in a significant number of animals. The situation in which cows or heifers do ovulate but are not observed being mounted by other cattle is often referred to as "silent heat".

The interval between periods of estrus in the same cow determines the length of the estrous cycle. The normal pattern of estrous cycles is determined by cyclical changes in the ovaries of an animal. In Figure 61, the top row begins with a ruptured (ovulated) follicle showing the egg that has been released. The development of this ruptured follicle into a mature corpus luteum and the later regression is indicated further on the top row of Figure 61. The corpus luteum prevents ovulation until it re-

gresses, apparently by the production of a hormone called Progesterone. This can be considered as the "natural" method of control of the estrous cycle.

On the bottom row of Figure 61, the growth of the follicle destined to rupture at the next estrus has been depicted in a schematic manner. The follicle, particularly at its mature size, has been associated with the production of estrogens. Estrogens are the hormones which cause the animal to demonstrate estrus. Shortly after the end of estrus, about 10 hours on the average, the follicle will ovulate. Ovulation refers to the rupture of the follicle so as to allow release of the enclosed egg. Maximum fertility is realized when the time of ovulation and the time of breeding are in the proper relationship. The proper timing of insemination is near the end of estrus or about 12 hours after estrus is first noted. Thus the semen is in the reproductive tract about 10 to 16 hours prior to ovulation under the best conditions.

Method of Estrus Synchronization

Various methods are theoretically available to artificially control the estrous cycle of the cow in a manner to be of more convenience and economic value to the livestock producer. Many methods have been studied but one method has been most extensively studied and appears to hold most promise at present. This method is to attempt to imitate the corpus luteum in the manner by which estrus is delayed. The corpus luteum began to receive a good deal of attention during the first 40 years of this century. During the 1930's, much progress was made in the isolation and identification of progesterone from the corpus luteum. During the 1940's, injections of progesterone into various farm animal species were made at the University of Wisconsin. It was demonstrated that the injection of progesterone could indeed delay the time of next estrus and ovulation even though the corpus luteum regressed. The synchronization of estrus was accomplished by injection of progesterone in a group of animals until the corpus luteum of most animals had regressed. Most of the animals had become dependent on the progesterone to inhibit estrus, then estrus occurred shortly after the last progesterone injection.

In Figure 62, the mature follicle has been illustrated to persist beyond the time of regression of the corpus luteum. The num-

ber of days which the follicle must persist without ovulation will depend on the individual cow. Then upon withdrawal of progesterone treatment, the follicle is allowed to ovulate as illustrated in the far right figure.

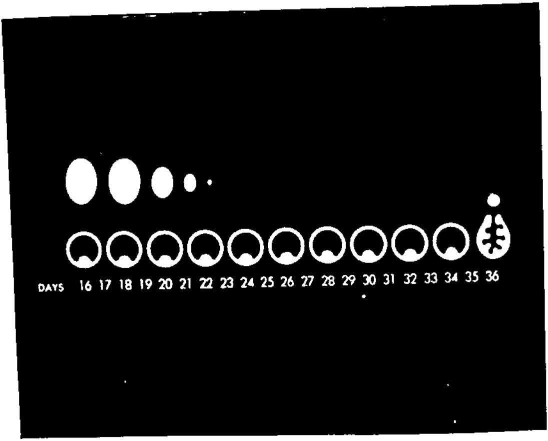

FIGURE 62. Inhibition of ovulation with progestogen followed by ovulation upon withdrawal of treatment.

USE OF SYNTHETIC PROGESTOGENS

During the 1950's, chemical synthesis of synthetic progestogens (progesterone-like compounds) received much attention in the pharmaceutical industry. One compound which had greater oral potency than the parent hormone, progesterone, began to receive widespread attention by researchers in large animal reproduction. This compound, called medroxyprogesterone acetate (MAP), was demonstrated to be capable of inhibiting estrus and ovulation in cattle in a manner which would produce synchronization of estrus.

Two figures are used to illustrate the use of Repromix*

*Registered Tradename, the Upjohn Company.

(MAP) to synchronize estrus. In Figure 63, the values along the left represent the days from next expected heat in a group of cows at the time that Repromix feeding is begun. For example, *1* indicates that the cow would have been in estrus *and ovulated*

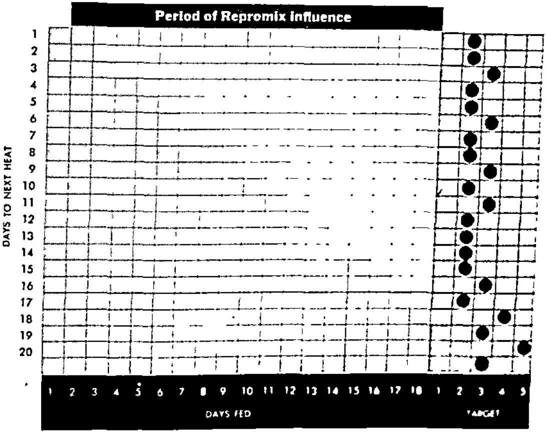

FIGURE 63. Illustration of manner in which individual estrous cycles are synchronized by ovulation inhibition.

one day after Repromix feeding began. The open area indicates that this cow will depend on Repromix for a long period of time to inhibit ovulation. *Additional cows will become dependent upon* the progestogen each day until nearly all cows have been influenced by progestogen treatment. The cow represented on the left side by *20* is one which will be near estrus at the time of first progestogen feeding. This cow will be in estrus (represented by the dot) during our "target" period for breeding. The object of estrus synchronization is to delay estrus in all other cows until this cow will be ready to return to estrus. It should be noted that more cows become dependent upon the progestogen to carry them into the target period as time progresses. A failure to receive the progestogen during the treatment period allows certain

cows to ovulate and these cows may not be synchronized. Thus it is essential that each cow receive the progestogen daily in a uniform manner.

In Figure 64, a typical response to synchronization with a progestogen has been shown. The left-hand column represents the percentage of estrous cycles which began at various days after last feeding. Synchronization was typified in this instance by a high proportion of estrus being observed at two (45 per cent)

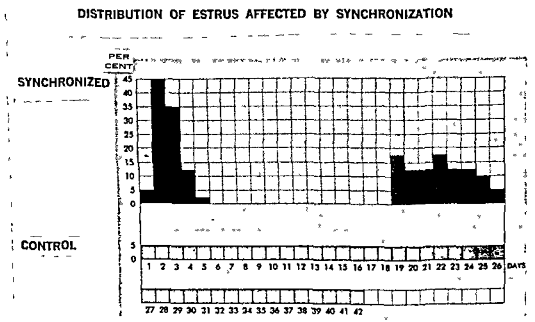

FIGURE 64. Distribution of first and second estrous periods of a group of synchronized animals compared to expected distribution in control animals.

and three (35 per cent) days after last feeding. The actual interval from last feeding may be influenced by the progestogen used or the dose of progestogen. The second estrous cycle of most treated cows will occur in a 6 to 8 day period between 18 to 26 days after last feeding. Compare this situation to control cows in which about 5 per cent of the cows will be in estrus each day and about 20 per cent of the cows would have a second estrous cycle in a 26-day period. The advantage to the rancher is primarily to have his cows ready to be bred in a short period of time. To realize this advantage, the rancher must be capable

of detecting estrus in his cows so that they may be inseminated at the proper time. To accomplish the same goal, namely two opportunities for insemination, in a group of unsynchronized cows would require about a 42-day period of estrus detection and insemination. The cows which conceive at the first and second cycles after synchronization treatment should also demonstrate a grouping of calves at calving time. The extent to which calving is grouped and calves are more uniform due to age of birth will be related to the proportion of the herd which conceives at the various post-treatment estrous cycles.

Considerations Prior to Synchronization

The above sections have attempted to discuss the normal estrous cycle and how it may be modified to an advantage for the rancher. The animal in which estrus is to be synchronized has to be *experiencing normal estrous cycles. There is no evidence* for the correction of abnormal reproductive behavior by agents for estrus synchronization. Two somewhat normal situations exist which must be considered prior to embarking on an estrus synchronization program. Puberty may be defined as the time at which the heifer begins to experience normal estrous cycles. If the heifer has not yet begun to have normal estrous cycles (prepuberal), then there may be no estrus period to synchronize upon withdrawal of treatment. The second situation is the period following calving during which cows do not *experience normal* estrous cycles (post-partum anestrual period). The average interval for cows may be on the order of 35 days, under ideal circumstances, to 80 or more days, under other circumstances. Delays in puberty and long periods of post-partum anestrus can be influenced by disease, nutritional status, and other management situations. It has not yet been demonstrated that progestogen treatment will initiate estrous cycles in either situation. It has been demonstrated with one progestogen (MAP) that treatment after calving does not *interfere with the resumption* of normal estrous cycles at the expected time.

The following questions must be answered satisfactorily by a rancher before he embarks on an estrus synchronization program with oral progestogens:

1. Are the animals to be synchronized reproductively normal and experiencing normal estrous cycles?

a. Good management program.
b. Proper nutritional status and health program.
c. Adequate interval from calving for cows.
d. Heifers of proper age and size for breeding.

2. Will it be possible to administer the progestogen-containing feed daily in a uniform manner for a period of about 18 days?

a. Pre-treatment period to accustom animals to feed to be used.
b. Proper mixing of drug in feed.

3. Are we capable of detecting estrus in the cows in an efficient manner?

4. Are my facilities adequate to allow sorting of the cows in estrus so that they may be inseminated at the proper time?

5. Can up to one-half of the cows be inseminated on the same day if they are in estrus?

6. Is the semen of good quality from a recognized source and the inseminator experienced or properly trained?

The most important item to keep in mind is that estrus synchronization provides the tool for more efficient scheduling of your insemination program.

Data From Studies with MAP

The first phase of studying the effectiveness of MAP was to determine the appropriate dosage to use. The studies which formed the basis for recommending 180 mg. daily have been reported elsewhere (Zimbelman, 1963). Several sources of data on MAP will be summarized, fuller accounts of the various studies are available in a separate publication (Repromix Technical Manual, 1965).

The data from six trials carried out at the Upjohn Farms were summarized in Table 112. At a range of doses, 196 (92 per cent) of 214 treated animals were considered synchronized. The percentage of all treated animals becoming pregnant at the synchronized service was 47 per cent, this varied from 26 to 75 per cent in the various trials. The conception rate of all untreated cows at the first service was 69 per cent, which was slightly below the 78 per cent, for the second service of synchronized cattle. Thus any reduction in conception rate was only temporary.

Of more practical significance to the rancher would be the

proportion of the initial group conceiving in a particular period of time. In Table 113, the data showed that a slightly higher percentage (76 per cent) of treated cattle had conceived within a 26-day period than did control cattle (69 per cent). These values were quite high in all trials. The percentage becoming

TABLE 112.—SYNCHRONIZATION AND CONCEPTION RATES IN UPJOHN REPRO-MIX STUDIES

	DAIRY HEIFERS	BEEF HEIFERS	BEEF COWS	ALL GROUPS

pregnant at two services, regardless of the time of the service, was 88 and 89 per cent for the treated and control groups, respectively.

A total of nine of the earliest beef cattle trials supervised by university personnel in accordance with the present recommendations for use of MAP have been summarized in Table 114. The mean percentage considered synchronized, based on detected estrus at first cycle, was 88 per cent in these nine trials and ranged from 75 to 100 per cent in various trials. The conception

TABLE 114.—SUMMARY OF NINE UNIVERSITY BEEF CATTLE REPROMIX STUDIES

Number of animals	Repromix	606	
	Control	383	
	Total	989	
Synchronized†		Mean*	Range*
		88%	75-100%
Conception rates at first service‡	Repromix	31%	24-55
	Control	55%	44-70
Conceived with two services§	Repromix	63%	38-82
	Control	69%	44-89

*Mean value and range for all trials.
†Based on observed estrus.
‡Percentage of those bred in some instances.
§Percentage of entire group in all instances.

rates of all groups tended to be somewhat lower than the six studies of Table 112, but the relationship of control to treated groups was quite similar. The conception rate at the synchronized service was somewhat lower (31 per cent) than in untreated cows (55 per cent) and ranged from 24 to 55 per cent in various trials. The percentages conceiving with two services were 63 and 69 per cent for the treated and control groups, respectively. Data on the first 26-day period were not available on several groups in these studies so are not reported here.

During 1962-1963, there were reports on the use of Repromix in 52 commercial beef herds involving about 3,000 treated animals. The purpose of this field testing was to determine the degree to which ranchers could effectively use an agent to synchronize estrus. Complete information, including control animals, was available on 13 of these herds (Repromix Technical Manual, 1965). In 1964, a total of 18 trials was set up so as to obtain

complete information on each trial using *recommended dosages* and feeding procedures based on the results of earlier field trials. In addition, certain herds will be used to obtain more detailed information on calving and age of calves at weaning from control and treated animals. The data from all of the 18 trials conducted in 1964 are shown in Table 115. In these studies, particular emphasis was placed on days 1 to 5 and days 18 to 26 after last feeding (ALF) in the analysis of the data. The mean percentage synchronized (estrus days 1 to 5 ALF) was 78 per cent

TABLE 115.—SUMMARY OF 18 REPROMIX FIELD TRIALS IN 1964

Number of animals	Repromix	1,975	
	Control	831	
	Total	2,806	
Synchronized*		Mean‖	Range‖
		78%	56-100
Conception rates at first service†	Repromix	36%	11-54
	Control	51%	27-83
Conceived within 26-day period‡	Repromix	57%	35-79
	Control	37%	20-53
Conceived with two services§	Repromix	62%	39-81
	Control	65%	39-90

*Observed in estrus days 1 to 5 after last feeding of Repromix.
†Percentage of those bred which conceived at first insemination, regardless of time.
‡Percentage of entire group which conceived within first 26 days after last feeding.
§Percentage of those bred which conceived with one or two inseminations regardless of time, up to 42 days maximum
‖Mean and range of 18 values.

be turned with the herd for additional services. The tendency for more of the synchronized group to be pregnant within 26 days than of the control group should be explained. At this time, it appears that this was due largely to more complete detection of estrus and to more animals receiving two services when synchronized. Differences between the data from field trials and that in Tables 112 to 114 are believed to be reflections of: (1) the incidence of prepuberal heifers or post-partum cows not experiencing normal estrous cycles, and (2) the efficiency of estrus detection under range conditions compared to research situations. No attempt was made in the field trials to select only cows having estrous cycles prior to use because this would not represent the manner of use under practical ranch conditions.

Perhaps the data in Table 112 can be considered as a goal for reproductive performance under range conditions. If so, then it seems apparent that significant gains in reproductive efficiency of beef cattle could be made. Research directed toward definition of improved reproductive performance would be of benefit with or without estrus synchronization. As indicated by the range of values in Table 115, certain herds did quite well with up to 79 per cent conceiving in one herd in a 26-day period.

The Future in Estrus Synchronization

Additional research on agents for estrus synchronization will probably be directed to four major areas:

(1) More potent or more economical agents for ovulation inhibition.

(2) Agents which work by a different mechanism of action.

(3) Methods of administration other than via the feed.

(4) Means of improving conception rates of beef cattle.

Past research has touched upon all of these areas but renewed interest may be generated. In terms of more potent progestogens, one such compound has been reported upon in several places recently. A progesterone derivative called CAP has been reported effective in cattle at about 10 mg. daily (Van Blake *et al.*, 1963). Our own research has turned up several other compounds which inhibit ovulation in cattle at doses of 10 mg. or less daily. More potent compounds are advantageous only if they result in a more favorable economic picture or have an improved performance. Only additional testing and time will determine

whether or not more potent agents do prove to be more useful.

Substances with new mechanisms of action are theoretically possible. Drugs which stimulate estrus (estrogens) or ovulation (gonadotropins) in large groups of cattle have not proven of practical value in past studies. These and other similar agents probably will continue to receive more attention by some researchers.

Methods of administration other than the feed would be more practical under some management situations. A report on the use of vaginal sponges impregnated with progestogens in Australian sheep will probably stimulate similar studies in cattle. Procedures using prolonged absorption from a single injection or implantation of a progestogen have not lived up to their promise, apparently due to failure to achieve a sharp cut-off with poor synchronization as a consequence.

Attempts to improve conception rates of cattle have been made for many years. We do not yet have sufficient knowledge to characterize the several reasons for the lowered conception rates encountered in many herds at present. Until we understand the causes and means of overcoming lowered conception rate under "natural" conditions, we will very likely not make significant progress with a lowered conception rate in synchronized animals.

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ness to make the management changes necessary for artificial insemination and estrus synchronization will develop at an unpredictable rate. The basic motivating factors will probably be: (1) a desire for replacement heifers with a greater genetic capacity for production, and (2) a recognition of the need for increased reproductive efficiency of beef cattle under commercial conditions.

Summary

The use of hormones to control the estrous cycle of cattle was discussed in relation to artificial insemination. The normal reproductive cycle of the cow was reviewed, pointing out those features important to the synchronization of estrus. A brief description of the manner whereby progesterone injections were used to synchronize estrus was illustrated by two figures. The use of Repromix, a feed premix containing a synthetic progesterone derivative, to synchronize estrus was discussed. It was pointed out that synchronized animals may be inseminated twice during about the first 26-day period after feeding Repromix for 18 days. Data on the percentage of synchronization and fertility are available on more than 5,000 cattle used in research at the Upjohn Farms, in university studies, and in field trials on commercial ranches. The results were influenced by the normal reproductive performance of the group to be studied, particularly in respect to whether the animals were experiencing normal estrous cycles. The detection of estrus for proper timing of insemination of the cattle was stated to be another important factor. A discussion of important considerations was made to aid the individual rancher in planning for an artificial insemination program using estrus synchronization. An attempt was made to define the areas of future research in estrus synchronization. Areas considered were: more potent compounds; compounds with different modes of action; different routes of administration; and improvement of beef cattle reproductive performance.

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D. E. BARTLETT

Artificial Insemination

The accumulated total of cattle serviced by artificial insemination (A.I.) in the U.S.A. is now about 100,000,000, and the annual rate of cattle inseminated in the world is now approximately 50,000,000. For 1964, the U.S.D.A. has reported a total of 6,-165,599 dairy cattle inseminated with semen of dairy bulls, 1,117,395 dairy cattle inseminated with semen of beef bulls, and 464,959 beef cattle inseminated with semen of beef bulls, for a total of 7,747,953 cattle inseminated.

The year 1964 is the first year the U.S.D.A. has reported beef-to-beef data. It is evident that A.I. of beef cattle has increased during the past several years from a few thousand annually to a total which may in 1965 exceed 500,000 and involve almost two per cent of the estimated beef cattle population of the U.S.A.

Reference to Table 116 reveals the fact that beef A.I. has

TABLE 116.—GROWTH OF A.I. BY YEAR IN DAIRY AND BEEF CATTLE AS REPORTED BY U.S.D.A., D.H.I.A.

YEAR	DAIRY	YEAR	BEEF
1939	7,359	1959	
1940	33,977	1960	
1941	70,751	1961	
1942	112,788	1962	
1943	182,524	1963	225,239
1944	218,070	1964	464,959
1945	360,732	1965	
1946	537,376		
1947	1,184,168		

grown as fast, if not faster, than dairy A.I. There have been differences, however. Beef A.I. has simply involved application of an already well-developed technology to another and somewhat more difficult animal husbandry environment. Growth of dairy A.I. required the development of a completely new technology and, simultaneously, its practical implementation.

Dairy A.I. was nourished by the agricultural colleges, extension services, the U.S.D.A., purebred associations, and related dairy

TABLE 117.—BEEF A.I. IN 1964. TEN LARGEST A.I. ORGANIZATIONS IN TOTAL OF BEEF TO BEEF SERVICES. FROM U.S.D.A., D.H.I.A.

ORGANIZATION	BEEF COWS INSEMINATED
American Breeders Service, Inc.	102,578
Curtiss Breeding Service, Inc.	43,000
Midwest Genes, Inc.	35,977
Armour & Company B.C.I.	30,318
International Beef Breeders	30,000
Central Ohio Breeding Association	28,971
All West Breeders	18,827
Cache Valley Breeding Association	13,125
Southern Illinois Breeding Association	10,902
Eastern Iowa Breeders	9,662

interests. It benefited from the good efforts of many hundreds of trained and influential people whose personal incomes were derived from public or non-A.I. sources.

Beef A.I. has been largely a project of the A.I. industry. There has been but little encouragement or participation by public institutions and even less outside subsidy (Table 117). Tacit postures and oppositions from covert to overt are still being encountered.

A.I. has been received by the beef cattle industry with the broadest variety of reaction. However, by now, it is surely clear to all that A.I. is neither going to spread like a pox nor is A.I going to end all sales of purebred bulls. A.I. will be neither the saviour nor destroyer of the beef cattle business. Allegations that herds cannot be kept on A.I. indefinitely or that A.I. offspring are "weak" or "different" just aren't supportable. Some dairy herds have been on A.I. exclusively for almost 20 years and the successive generations of offspring are normally functioning cattle. Even the most reactionary should know by now that cattle aren't made sterile by A.I. and that, really, the only thing artificial in artificial insemination is its name—now recognized as an

unimaginative and unfortunate choice of words by its developers.

In responsible hands, A.I. of beef cattle is no more disposed to result in widespread appearance within a breed of those hereditary defects which are transmitted upon the 1:2:1 pattern of expression, characteristic of the Mendelian simple recessives, than is A.I. of dairy cattle. In this regard, more than 25 years in breeding 100,000,000 dairy cattle in the U.S.A. by A.I. speaks clearly for itself.

Allegations raised against beef A.I. to the effect that hereditary defects such as "snorter dwarfs" will become rampant should be recognized as "red herrings" of the same species that were once raised against large-scale use of dairy bulls in A.I.

The fact is, when intelligently employed, A.I. becomes a most valuable procedure in controlling and minimizing those harmful hereditary defects already extant within our cattle population.

A.I. is just another technical tool, the value of which is determined directly by the knowledgeability with which it is employed. Requisites for successful use of A.I. for beef cattle are about the same as those for obtaining the maximum number of calves over the minimum period of time from natural service.

In the past few years, most of the purebred beef cattle associations have modified their regulations in regard to registering calves from A.I. Three questions, (1) number of registered females inseminated for each of the past five years? (2) number of calves registered from A.I. matings for each of past five years? (3) What ten bulls have greatest number of registered offspring—by year and by bull? elicited responses as tabulated by breed in Table 118. Respective regulations relative to A.I. are also noted.

It is apparent that most purebred beef cattle associations have not been maintaining precise records as to the number of calves from A.I. matings they have been registering.

The reply of the American Aberdeen Angus Association is especially interesting in that they report 16,956 A.I. calves registered in 1963 and 23,219 A.I. calves in 1964, during which latter year a total of 372,737 were registered. Thus, 6.1 per cent of the total of Angus cattle registered were known to be from A.I. matings. Additionally, the Secretary stated that they knew of wider use of A.I. within the breed and hoped in the future to have more accurate records.

Of interest is the fact that one Angus bull had 683 calves

TABLE 118.—BEEF PUREBRED ASSOCIATIONS AND A.I.

BREED	QUESTIONS ASKED JANUARY, 1965 (1) Number of registered females inseminated for each of past five years? (2) Number of calves registered from A.I. matings of past five years? (3) What ten bulls have greatest number of registered offspring—by year, by bull, if possible?	CONDITIONS OF ACCEPTANCE FOR REGISTRATION OF PROGENY FROM ARTIFICIAL INSEMINATION. SPECIAL REQUIREMENTS OR COMMENT AS OF JUNE, 1965.
Angus	Records incomplete. Total calves by A.I. registered: 16,936 in 1963 23,219 in 1964 One bull had 683 calves registered in 1964. Ten bulls had more than 300 calves each registered in 1964. Secretary states: "We know . . . wider use within the breed . . . hereafter we will have an accurate record of them."	1. Bulls must be blood-typed. 2. As of April 16, 1965, regarding bulls used artificially: "Bulls calved in the U.S. on or after May 1, 1965, and all bulls purchased outside the U.S. on or after May 1, 1965, will be governed by the one owner rule. All other bulls will remain under the three (3) owner rule. . . ." 3. The transfer, transfer and retransfer and sale and repurchase in order to circumvent the intent of our Rules is considered a violation. . . . "get" of animals involved . . . ruled ineligible.
Brahman	Not tabulated and impossible to ascertain. Would provide if available. Recording Secretary estimates 25 or 30 calves by A.I. registered per year.	1. The breeder, who is the recorded owner of the dam at the time of service, must also be the recorded owner of the sire, or one of not more than four owners, except* in the case of a bull from which semen is on storage and the bull is sold, then the seller must use the semen provided the buyer agrees in writing and provided the number of ampules on hand is recorded with the Association. 2. A list of bulls used artificially must be filed with the Association annually by each ranch or ranch organization. 3. It must be stated upon the Application for Registration that the calf was produced by artificial insemination. 4. The use of frozen or otherwise preserved semen is permitted. 5. Upon the death of a bull from which semen has been collected for artificial insemination, the owner of the bull must immedi-

		ately notify the Association and state quantity of semen in storage. *Amended 2/21/63.
Charolais	Registrations between June 1, 1964, and June 1, 1965, totaled 245.	A.I. permitted in four categories: (1) Unrestricted (2) Restricted (3) A.I. within herd (4) A.I. from foreign semen and imported bulls. Blood-typing not required. Consult A.I.C.A. rule book for details.
Hereford	Do not have data. . . . impossible . . . since a number of breeders use their bulls both artificially and naturally. . . . do not have similar information *for Hereford* bulls which have accumulated greatest number of offspring.	1. Meet usual requirements of eligibility for registration. 2. The sire and dam were in the same recorded ownership at the time the calf was conceived. 3. The sire was alive at the time of service. 4. The use of frozen or otherwise preserved semen is acceptable to the Association provided the sire from which the semen was taken is alive at the time the artificial mating was made to produce the calf being registered. 5. No application for entry or transfer of an animal, which shows such animal to be owned by more than four owners, or by a partnership having more than four partners, shall be accepted for entry in the American Hereford Record. 6. Additionally, as of April 15, 1965: a) Breeder must obtain Association permit to record calves from A.I. b) Bull must be blood-typed. c) A.I. calves must be identified on application for registry.
Polled Hereford	Information not available. Would involve an expensive and time consuming process in obtaining data on ten . . . bulls with greatest number of registered offspring.	1. Polled Hereford calves produced by artificial insemination are eligible for registration *only when the sire and dam of the calf were in the recorded ownership of the same herd at the time the calf was sired.* 2. Breeders should use the breeding certificate portion on the back of the application for entry card to designate calves produced by artificial insemination. Please write in the same "Calf was produced by artificial insemination." *When the bull dies, the semen dies.* 3. Additionally, as of April 15, 1965: Bulls must be blood-typed.

TABLE 118 (*Con't.*)

Red Angus	Approximately 125 calves registered from A.I. matings in 1964.	1. Calves by A.I. are eligible for registry. 2. Number of owners of sire are unlimited. 3. Application for registry must be accompanied by a signed statement from person providing semen. Also a signed statement from both the owner of the sire and breeding unit, if different. 4. No restrictions on use of semen after sire is dead. Blood-typing of sire not required.
Santa Gertrudis	Prior to 1963, 938 animals by A.I. recognized when semen purchased from commercial processing organization. Presently, estimated that 10 to 15% of approximately 15,000 animals accepted each year are from A.I. The number of cows bred by A.I. is on the increase. A great many breeders are now using A.I. as a mating procedure in their own herds with semen from bulls in which they have full ownership or bulls in which a breeder is one of not more than four owners.	1. The rules and regulation of SGBI governing purebred Santa Gertrudis, and herds being graded-up to purebred through successive top crosses, *shall be the same whether breeding is by natural service or by artificial insemination provided:* 2. When artificial insemination is employed in the herds of a given ranch or ranch organization the males and females must be owned by such ranch or ranch organization. 3. The word "owned" as it applies herein shall mean that the ranch or ranch organization must be the sole owners of the females and must be one of not more than four owners of the bull. The terms "ranch" or "ranch organization" used herein mean bona-fide ranching operators, and may not be extended to include organizations whose business is the collection or processing of semen for the purpose of marketing.
Shorthorn	Do not have the figures.	1. Qualified Junior members who have requested permission and it has been granted. 2. Owners of both the sire and dam of the calves. 3. Owners of the dams and an interest in the sire where no more than three owners are involved. 4. Transfer and re-transfer to circumvent these regulations will not be permitted.

registered in 1964 and ten Angus bulls each had more than 300 calves registered in 1964.

There have been happenings of significance during these five years of growth and development which have served to further interest in beef A.I.:

1. Continued progress is being made in methods for reliable selection of beef sires *worthy* for use in large-scale A.I. Performance standards have been developed and established by several purebred beef associations. Progeny testing of bulls has become a reality.

2. In 1965, almost 500 sires of the beef breeds are in use by commercial A.I. organizations. Of course, semen from many of these bulls is used preponderantly for the insemination of dairy cattle, and these bulls are not all of extraordinary genetic merit. However, some of the beef bulls being offered are the product of deliberate and objective, mathematically quantitated, programmed methods of evaluation and selection: birth weights, weaning weights, weight per day of age, gain per day in feedlot, efficiency of feed conversion, and carcass qualities have been established for offspring. They were selected because in tests their offspring proved superior; subsequent offspring of such bulls from A.I. are performing well in feedlots.*

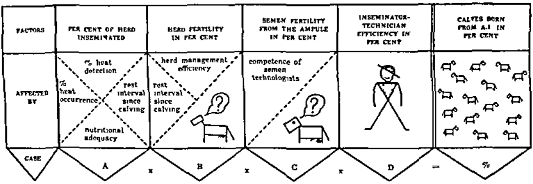
3. There has been recognition of the significant frequency of occurrence of certain infectious venereally transmitted diseases affecting reproduction of beef cattle for which bulls are the disseminators and permanent reservoirs. From Colorado, it has been reported that 45 of 83 herds with breeding difficulties in Colorado and adjacent states examined, by bacteriological methods, were found infected with bovine vibriosis (Heorlein *et al.*, 1964). From Utah, it has been reported that 7.5 per cent of 823 beef bulls tested in Utah and surrounding states were found infected with bovine venereal trichomoniasis (Johnson, 1964).†

4. Data are accumulating from the insemination of many beef herds. Some results are very poor and others are remarkably good, with direct relationship to nutritional preparation typically

It is improbable that any of the above-indicated factors are ever at a 100 per cent level. The estimates used herein for illustration are intended to be just that—reasonable estimates. The optimal inseminator-technician level is set at 100 per cent as it is the most controllable factor.

Table 121 makes clear the realistic expectations from a "one-cycle" period of breeding. Likewise, it illustrates not only the principles involved, but the penalties resulting when individual

TABLE 121.



1. Ideal situation.

   95 x 90 x 95 x 100 = 81.2

2. Good per cent of herd inseminated (85%); other factors ideal.

   85 x 90 x 95 x 100 = 72.7

3. Poor per cent of herd inseminated (60%); herd fertility lowered 10%; other factors ideal.

   60 x 80 x 95 x 100 = 45.6

4. All factors lowered 10%.

   85 x 80 x 85 x 90 = 52.0

5. Per cent of herd inseminated and technician efficiency lowered 10%; other factors ideal.

   85 x 90 x 95 x 90 = 65.4

6. Fair per cent of herd inseminated (70%); semen fertility lowered 10%; other factors ideal.

   70 x 90 x 85 x 90 = 48.2

7. Poor semen fertility (50%); other factors ideal.

   95 x 90 x 50 x 100 = 42.8

8. Poor technician efficiency (60%); other factors ideal.

   95 x 90 x 95 x 60 = 48.7

9. Poor semen fertility (50%); poor technician efficiency (60%); other factors ideal.

   95 x 90 x 50 x 60 = 25.6

factors are less than optimal. The compounding effect when more than one factor is less than optimal is made clear and should be especially noted. Optimal results from either A.I. or natural service necessitate each contributing factor's being at an optimal level.

It should be especially noticed that a single weak factor never "averages out." Per cent calf crop is *not* the average of the component factors but the product of the component factors. Ob-

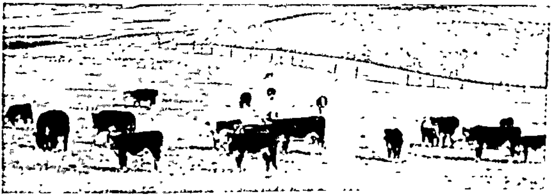


FIGURE 65. Heat observation, insemination season, and birth of artificial inseminated calves are well established events in the yearly routine on this Montana ranch.

viously the product must always be lower than the smallest factor.

$$\frac{A+B+C+D}{4} = \text{calves born from A.I. in per cent}$$

Surely the most important development in beef A.I. stems simply from the practical experience of having inseminated many beef cattle and from having observed varying degrees of success under differing methods and conditions. Comment is offered under each of the independent component factors indicated previously.

Per Cent of Herd Inseminated

When we observe and compare different beef herds under A.I., it seems quite probable that the first factor, *Per cent of Herd Inseminated*, has been not only the most widely variable, but the factor which has been, when inadequate, preponderantly responsible for suboptimal or unsatisfactory results. Obviously, if but a low percentage of the cattle making up a herd is inseminated, it follows that attainment of the objectives of the A.I. program will be proportionately disappointing. Subfactors relating to the per cent of the herd inseminated are several.

Cows must not be pregnant and must be cycling and displaying heat in order that heat signs may be recognized and inseminations carried out. Sometimes there has been failure to recognize beforehand that a herd's annual *calving season extended too long* (6 months, 9 months, 13 months) so as to make impossible having, within a reasonable period, sufficient qualified cows available for A.I. (i.e., not pregnant and not less than 50-60 days since calving).

Especially frequent has been the situation of a high proportion of the *cows being too long delayed after calving before return to heat.* Too many cows were simply not yet cycling and showing heat at the time when being observed for heat. The heat observers and the inseminator-technician were prepared and ready —but, the cows were not. If there has been any one most common and most intense technical problem in beef A.I., this has been it.

Extended delay in return to heat is, of course, no less a problem in natural service. A.I. records have been serving to more clearly define the facts. Fortunately, *this single greatest problem* has been the subject of recent and most significant research in beef cattle management. Workers at the Beef Cattle Research Station, Fort Robinson, Nebraska, led by Dr. James Wiltbank, have made outstanding contributions toward solutions which, in the opinion of this writer, have been fundamental in furthering adaptation of the A.I. technique to beef cattle, especially under range conditions. This research may prove to be among the most important contributions toward betterment of beef breeding practices, A.I. or natural service, of this decade (Wiltbank *et al.*, 1962).

Demonstration of the singular importance of adequate energy, T.D.N. (not protein), and of the levels required both before and after calving for resumption of cycling and normal fertility during the second and third month after calving, is no less fundamental to the successful breeding of beef cattle by natural service than by A.I.

The make-or-break importance of *adequate phosphorus intake* for normal reproduction, especially for estrous cycling, has been well established.

Remarkable skill in the art of heat detection has been quickly acquired by many ranch people. The ability to "read" cows well has become a source of justifiable pride; likewise, has the art

of cutting and moving those in heat efficiently in order that they can be effectively passed through a chute for their insemination.

Diligent heat observers develop confidence in their abilities to recognize cows in heat with no less accuracy than a bull. In fact, experienced heat observers seem to become remarkably contemptuous of bulls and their abilities—especially toward their habit of giving undivided attention to a single conquest, while

Aids to heat detection seem to have found neither a necessary nor lasting place in beef A.I. Devices to be activated by the contact pressure of riding animals have been designed to be attached to the tailheads of females being watched for heat. These devices are not only expensive, but have tended toward detachment and malfunction. Their greatest usefulness may be found in small herds with absentee management. Continued improvement in these devices would surely increase their usefulness and acceptance.

Detector animals such as steers stimulated by injection with male sex hormone and bulls which have been vasectomized and subjected to mutilating operations involving amputation, deviation, or pocketing of the penis to preclude genital contact have not found very general or continued acceptance for a variety of most practical reasons. Either these males lost interest and didn't work, or they were found to mix disadvantageously the in-heat females within the herd. Too much exclusiveness of interest was commonly noted. Genital contact of detector animals can be responsible for continued spread of harmful venereal diseases.

Various types of marking harnesses by means of which some identifying color-mark can be transferred to in-heat females when they stand for riding have been developed and tried. Aprons to be worn by detector bulls to preclude contact of the penis with a female proved unsatisfactory.

The usual conclusion toward use of detector animals has been that a conscientious human observer when sufficiently experienced to be confident can do the job better alone. Dependence upon heat detection aids seems to terminate when human observers have mastered their tasks and when it is possible for them to devote undivided attention to their tasks.

The possibilities of and for *synchronization of estrus* through administration of hormones, making possible insemination of an entire herd within a few days, has intrigued both theoretical and practical people for many years. Synthesized hormones are now available for experimental purposes which effectively withhold the onset of estrus. Upon simultaneous discontinuation of the hormone effect, females respond by coming into estrus on or about the same day.

Experimental evaluation of products and methods is underway. The results being obtained suggest a useful potential; but, the total of advantages must be significantly greater than pres-

ently evident before wide acceptance. Probably the greatest hurdle to exploiting the mechanism of estrous synchronization is the anachronism of pharmacologically stopping estrous cycling in groups of cows when they aren't yet cycling—principally because of their prior inadequate energy intake.

It is quite apparent that successful artificial insemination of a given herd without estrous synchronization must be possible before artificial insemination with estrous synchronization can become possible.

HERD FERTILITY IN PER CENT

It is well established for both dairy and beef cows that fertility level does not reach an optimal level until about two months following calving. *Too early rebreeding*—natural or artificial—results, on the average, in low settling rates. Recent examples of such under beef A.I. conditions have occurred.

Proper nutritional status, especially in respect to energy, phosphorus, and vitamin A, is critical and imperative to normal fertility. Herds prepared nutritionally have been those with satisfactory settling rates. Inadequately prepared herds have proportionately lessened settling rates (Bartlett, 1964).

Specific venereal diseases of cattle, especially bovine venereal trichomoniasis and vibriosis, can play a role in the outcome of A.I. when an attempt is made to inseminate still-infected females exposed in the recent past through contact with infected bulls. Carried-over dry females, infected and infertile during the preceding year's breeding season, ordinarily will have recovered from their infection and regained normal fertility.

Accuracy in heat detection and proper timing of the insemination are of importance. There is no certainty for beef herds that superior results are obtained when cows observed in heat in the evening are inseminated the next morning, and those observed in heat in the morning are inseminated that same afternoon. However, such a regimen may work smoothly with the general management routines. Equally good results seem to have been obtained in many herds where inseminations were performed at one single convenient period each day.

Double insemination of each cow—night and morning—may increase settling rates as much as six per cent. However, the economic advantage of such a practice in commercial herds seems not to justify the added cost.

Natural nutritional and environmental conditions have commonly established a *traditional season for breeding* in each area. Attempting to breed a herd preceding this season when weather and nutritional resources are clearly unfavorable leads inevitably to difficulties.

"Out-of-season" insemination programs are being carried out successfully, but only when the nutritional requirements are

FIGURE 67. Artificial insemination offers exciting possibilities to cattlemen in countries with rapidly developing agricultures. However, knowledge and skill necessarily precede use of A.I. This group of cattlemen in Panama received A.I. training in U.S.A. procedures.

provided by means of adequate energy supplementation that is maintained for sufficient duration.

Semen Fertility From the Ampule in Per Cent

A principal advantage in A.I. is derived from the fact that the male factor for fertility can be supplied as, and at, a high level constant. When the semen used in A.I. is anything less than optimum, a principal advantage of A.I. is quickly lost.

A.I. is the most effective way of immediately stopping the spread of diseases transmissible at sexual contact. This necessitates, of course, that bulls used as sources of semen in A.I. be free from infectious venereal diseases and that the semen be properly processed.

One could cite numerous disappointments in beef A.I. results caused by semen of poor quality. Vibriosis has been transmitted

into beef herds with improperly processed semen. A large quantity of semen is known to have been frozen from at least one dairy bull just preceding diagnosis of his being infected with bovine venereal trichomoniasis. —And, today, bovine venereal trichomoniasis is even more frequent in beef cattle than in dairy cattle.

Many beef bulls do not produce completely normal semen. Most beef bulls occasionally produce abnormal semen. Conse-

FIGURE 68. Deseret Farms of Florida, Inc., at Melbourne, Florida, has pioneered use of A.I. to upgrade a very large herd of mixed beef cattle. In 1959 approximately 2,000 heifers and dry cows were inseminated; in 1960 approximately 2,700; in 1961 approximately 3,750; in 1962 approximately 4,600; in 1963 approximately 5,500; in 1964 approximately 7,650; and in 1965 approximately 9,000. A.I. usually began about March 15 and continued to August 1. Cattle were released to "follow-up bulls" after 45 days if no return to heat was noted and after having been inseminated twice. Sometime bulls were turned with cattle on Sundays. According to the herd management, pregnancy diagnosis percentages have varied from year to year, averaging approximately 76 per cent with the best year, 1964, being 79 per cent.

quently, a most critical decision in determining the outcome of a beef A.I. program is whether or not a specific beef bull should be used in A.I. Other critical decisions are made each time when it is decided whether or not to freeze each individual collection of semen. Further critical decisions are made when it is decided, postfreezing, whether or not a given collection of semen is suitable for use. Consistent quality control and adherence to highest laboratory standards are imperative. Decisions require objectivity and competence on the part of experienced technologists.

Approximately five per cent of collections of beef bull semen are rejected postfreezing from one large and stable group of beef bulls in order to assure consistently high fertility. And, before admittance, each of this group of beef bulls had been carefully screened for fertility characteristics, all were maintained under ideal conditions, and their semen collected regularly and processed by experienced, expert technologists.

Beef cattlemen would be well advised to select herd sires for

technicians have inseminated many cows badly and for a long while.

Since but very few inseminator-technicians bring depth of knowledge to their jobs, it is desirable that they be subjected to competent supervision and occasional retraining. Anything less than evidence of continuous striving for perfection—with each heifer and cow presented—on the part of an inseminator-technician is cause enough for management's making other arrangements. Excellent inseminator-technicians are available and more can be readily trained.

SUMMARY AND CONCLUSIONS

The technique of artificial insemination, principally as a means for making possible inexpensive, widespread exploitation of the economic value of scientifically selected, superior bulls within herds of commercial beef cattle, has been making rapid growth through the stages of technical development, evaluation, and acceptance.

A.I.'s capabilities in beef herds are being clarified.

With present day technology, whether or not the male factor for fertility (semen) is delivered to herds disease-free and as a high-level constant is, in essence, an elective decision.

Learning and accomplishing by beef cattlemen of the obviously new and unfamiliar requisites for A.I., as concentrating of the herd for observation, heat detection, handling of individual in-heat females, an act of insemination, although necessarily pursued with exactness, have constituted problems of far less magnitude than anticipated.

and especially during the months immediately before and after calving. Not-in-heat females are equally unobtainable objectives of A.I. and of bulls.

Breeding the beef herd by A.I. goes hand-in-hand with present-day *goals of shortening breeding seasons and achieving the* highest possible per cent of cows pregnant during the first three weeks of each breeding season. The nutritional requirements for such are quite well defined.

Except as an effective replacement for diseased or infertile bulls, A.I. is a cure for nothing in a troubled beef herd. Surely, A.I. won't work well when attempted as a solution for cows not coming into heat or for cows that are diseased or otherwise infertile. A.I. simply can't be expected to settle cows that couldn't be settled on the same day by a potent, fertile bull. There seems little doubt that if there is a mediocre job to be done in a marginal environment, bulls can do it better.

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G. T. EDDS

Reproductive Diseases in Cows

Beef cattle producers and specialists from the University of Florida, meeting to review the strengths and weaknesses of the present beef cattle production opportunities in Florida, determined that the relatively low conception rate for Florida's cattle producers was probably the most important limiting factor for effective competition with those in beef cattle production in other sections of the United States. In many other sections the conception rate varies between 75 to 85 per cent. It is believed that in many instances the conception rate in Florida would be between 55 and 60 per cent.

Whereas livestock producers of Florida will market approximately $250,000,000 of animal products during 1965, it has been estimated that disease losses account for at least $52,000,000 annually. Few other businesses can afford the luxury of losses approximating 20 per cent of gross sales and compete with others operating much more efficiently. Rather, serious attention is focused on analyzing the problems, their causes and prevention.

In order that proper evaluation of the reasons for this low conception rate can be made, it is necessary that the beef cattle producer keep adequate records on every cow. These records should include the date the cow was bred, the quality and healthiness of the calf produced, whether or not the calf was born naturally or required assistance, whether the placenta was retained and if treatments were required, which ones were used and how many were required to clear up the infection. Veterinarians and other qualified experts in this field have emphasized

the importance of healthy animals, adequate nutrition, good management, selection of cows conceiving by the second or third service, and culling those not settling unless sufficient reasons for the delayed conception rate can be determined. They point out the importance of proper rectal examinations for diagnosis of pregnancy, determining whether or not anestrus is a cause for the animals not being pregnant, whether or not the cow is suffering from metritis or pyometra, whether there may be mummified fetuses present, and the nature of the corpus luteum or the ovarian follicles.

Most authorities believe that an average of 1.85 services per cow is a normal ratio. The question naturally arises whether the cow or the bull is at fault as far as the low conception rate is concerned. Assuming the animal comes into heat regularly, ovulates a normal, healthy ovum which passes through a normal fallopian tube into the uterus where implantation may take place, if the quality of the semen is low, then lack of conception may be due to poor semen quality rather than an inadequacy of the cow.

If the animals have not conceived by the second or third breeding period, both the bull and the cow should be examined for possibility of vibriosis or trichomoniasis infections. There has been a widespread increase recently in the incidence of vibriosis in dairy and beef cattle throughout the United States. This disease affects both the cow and the bull. The prime cause of repeat breeding in cattle may well be vibriosis. If abortion has taken place recently, or if a mummified fetus is found on examination of the uterus, then one should suspect leptospirosis or possibly brucellosis as the infective organism. It is helpful if the veterinarian or the owner can collect either the vaginal discharge after abortion, the fetus, the placenta, or certainly blood from the animal which has aborted. These materials may be examined for suspected brucellosis, leptospirosis, virus diarrhea, infectious bovine rhinotracheitis, or infectious pustular vulvovaginitis. Other organisms which may also cause abortion on occasion are listeriosis, and certain of the fungi. The normal time for expelling the placenta after parturition is 3 to 10 hours. If more than 10 hours are required for the expulsion of the fetal membranes, then one should suspect pathological changes have occurred which may have been due to brucellosis or one of these infectious conditions.

Vibriosis, a bacterial venereal disease of livestock, has cost stockmen millions of dollars. The disease causes infertility, and the reduction in the number of calves makes it the most costly reproductive disease of beef cattle in the United States. According to an authority in the field, Dr. A. B. Hoerlein of Colorado State University, "Vibriosis has spread so rapidly during the past three years that hardly any range area in the United States is free of the disease. During the study newly infected cattle herds were found where pregnancy rates varied from 0 to 50 per cent with an average of nearly 30 per cent. This low incidence was due to vibriosis."

A new vaccine has been produced which will be distributed to ranchers through their veterinarians. The vaccine is designed to protect susceptible cattle from vibriosis. In infected herds replacement heifers are most likely to have severe losses. It may be profitable to vaccinate the whole herd to protect older cows which have missed previous infection or in which immunity has diminished. Much of the value of the vaccine will be to protect noninfected herds which could be exposed to vibriosis from other infected cattle. Duration of immunity from vaccination is not known at this time, but it is expected that annual booster revaccinations may be necessary to maintain high levels of immunity. Experiments are in progress to answer this question.

In an adjoining state 260 samples were obtained from 106 animals of which 92 were classed as normal breeders based on conception within the first three breedings. Of the 92 normal animals, 51 conceived on the first breeding, 29 on the second, and 12 on the third. Thirty-eight per cent of the 201 samples from the normal animals were bacteriologically sterile, whereas only 5 per cent of the 59 samples from the repeat breeders were sterile. The data indicates that in normal breeders most of the bacteria are saprophytic types and nonpathogenic.

In one herd, 46 difficult breeders were examined. In those, significant abnormalities of the reproductive tract were detected by rectal palpation in 37 animals. Yet the bacteriological culture failed to isolate any hemolytic streptococci. Only one coagulase positive staphylococcus and only three corynebacterial cultures were identified. Pseudomonas cultures were isolated from six of the cows indicating that it may be involved in individual herds.

Dr. G. T. Easely, of Oklahoma, has pointed out that *Staphylococcus aureus* is occasionally associated with infertility. They found this species present in 28 per cent of their samples from normal animals and 42 per cent of their samples from difficult breeders.

The failure to obtain any consistent evidence of bacterial infection in the difficult breeders in herds from which single samples were obtained emphasizes that bacterial infection is just one of the causes of difficult breeding. This probably accounts for the success reported by some workers with intra-uterine antibiotic therapy while others have failed to obtain beneficial results. To properly evaluate such treatments, the veterinarian, working with the herd owner, should carry out a bacteriological study concurrently with the therapy study.

Again, other workers have estimated that about 20 per cent of cows require three or more services for conception and that 6 to 7 per cent of the animals will be nonbreeders. Studies of these repeat breeding cows and heifers have indicated that fertilization may occur in 25 per cent of these difficult breeders or about five cows per 100. However, of the other 15 animals per 100 in which fertilization occurred, it was estimated that in about 12 to 15 cows the embryos died within the first 30 to 40 days after conception. This would be an explanation as to why the conception rate would range between 80 and 90 per cent. Six to seven animals per 100 do not conceive. So, with the

original 6 to 7 per cent that are nonbreeders, plus the additional 15 per cent that do conceive but lose their calves within the first month after pregnancy, the delivery of normal, healthy calves varies between 80 and 85 per cent. Gross abnormalities of the genital organs were observed in only 11 to 14 per cent of these repeat breeding animals. Of the specimens examined routinely in slaughtered cows and heifers, about 3 to 4 per cent showed sufficient abnormalities to cause sterility. This would indicate that perhaps half of the infertile animals could be expected to show gross abnormal diseases.

In a recent report from London a three-months-old fetus from a dairy cow in a farm where numerous abortions had occurred was examined within a few hours after abortion. Numerous colonies of a fungus developed from a two-day culture of the amniotic fluid, the fetal membranes, the cotyledons and heart tissues, while all other tissues remained sterile. This is one of the early reports on the isolation of a fungus as causing abortion in cattle. The fetal membranes are normally expelled in eight to twelve hours after parturition. Should they be retained for a longer period, manual removal is generally practiced. A common sequel to abortion in brucellosis is retention of the fetal membranes. With viable, single calves, the rate of placental retention is three times as high in brucellosis positive animals as in brucellosis negative ones. The rates of placental retention in a series of 542 parturitions appeared high in cases of abortion or stillbirth regardless of whether the animals were positive to brucel-

tion inhibits the uterine defense mechanism. Greater numbers of bacteria were recovered from experimentally infected uteri of rabbits and cows in the luteal phase than from uteri during the follicular phase or from ovariectomized rabbits and cows. Progesterone inhibited the bactericidal activity of the uterus against *E. coli.* Estrogen stimulated the clearance of the *E. coli* cells from the uterine lumeun. Ovarian hormones apparently influenced uterine defences through an affect on the leukocytic response. Progesterone prohibited the response whereas estrogen stimulated it.

Infectious bovine rhinotracheitis (IBR) generally occurs after the introduction of new cattle. If adequate case histories are obtained, it will be found that feeder cattle, in which this sequence has been consistently observed, have recently passed through several feed yards in-state as well as out-of-state. Its occurance in dairy cattle sometimes coincides with the importation of replacement stock.

The disease falls into two categories: a mild type, predominating in dairy cattle and a severe type in beef cattle. The maximum number of new cases on a daily basis usually occurs during the second and third week with the disease running its course by the end of the fourth to the sixth week. Occasionally it is persistant in the feedlot for several months.

The onset of IBR is sudden. In dairy cattle an abrupt cessation of milk production is the first indication of illness but, in beef cattle, the corresponding early signs are so mild that they may be detected only by those who have considerable experience. Salivation, a slight serous nasal discharge, congestion of the nasal mucus membrane, a temperature from 104 to 108 degrees or higher, or often manifestation of a certain amount of hyperexcitability, are the earliest definite observable signs. Respirations are accelerated and shallow, some degree of labored breathing is apparent, particularly if the cattle are moved or hurried. Lung sounds are essentially normal. Leukopenia has not been detected at any stage of the infection. In early reports on morbidity and mortality, a morbidity of 30 to 100 per cent was reported in the Colorado feedlots with a herd mortality of 2 to 10 per cent. In an extensive and prolonged outbreak in a large feedlot in California, R. E. Hoadley found that of 7,200 animals on the premises, 22.1 per cent became infected and 12 per cent of the infected animals died.

inhibits the uterine musculature and overcomes the estrus activity of the uterus, stimulates the uterine mucosa, causes glandular growth and the preparation of the uterus for the fertilized ovum, aids in placental development, and inhibits the estrous cycle during gestation. When the fertile egg reaches the uterus, it becomes attached to the endometrium.

Until attachment, the ovum is nourished by uterine milk secreted by the cells of the normal mucosa and by glands. During the period of the embryo, from 10 to 45 days, the fetal membranes are formed and become attached to the endometrium. The embryo grows to about an inch in length. The period of the fetus begins at day 45 and lasts until parturition. The interval between parturition and the onset of first estrus ranges from 32 to 69 days in dairy cattle and 51 to 80 days in beef cattle.

Failure of estrus may be due to lack of pituitary function, various functional ovarian diseases, uterine interference, or, in rare instances, failure of the ovum to mature. Failure to ovulate may be the result of cystic degeneration of the follicles; a cystic or degenerative corpus luteum is believed to follow ovulation failure. The cystic corpus luteum is softer than normal and does not have the normal dimple on the external surface. On rare occasions, lack of fertilization may be due to the egg being caught in the fold of the ruptured follicle or inflammation of the ovaries with adhesions of the fimbriated end of the oviduct to the ovaries so that the ovum cannot enter the oviduct (inflammation of the oviducts blocks them) or to infections which destroy or hinder the passage of the sperm or fertilized ova. Unseen abortions occur up to the 60th day of gestation but after that time abortion is usually recognized. Many early abortions are due to infection; others may be caused by a lack of a proper amount of progesterone or luteotrophic hormone.

Trichomoniasis is not a common disease but it is a possibility which should not be overlooked in the herd fertility program. It is characterized by a fairly high incidence of reproductive failure, early abortions and pyometra. Losses in affected herds are high. The venereal method of spread limits its overall losses in the cattle population as a whole. The causative agent, *Trichomonas fetus* lives only in the genital tract, and infection occurs at the time of actual service or more rarely by using infected semen for artificial insemination. The most common symptom is infertility. The history of a prolonged period of difficulty in set-

tling a substantial number of females, the number of females showing prolonged and irregular heat cycles, early abortion, and pyometra is characteristic of the disease. Trouble starts shortly after the introduction into the herd of a new breeding female or a sire.

Except in the case of very valuable bulls, treatment of the infection in the male is usually not practical, although recently success has been reported in treating infected bulls. Artificial insemination is one of the measures most useful in controlling the spread of this disease.

Endometritis is often considered the most common cause of infertility; some 80 per cent or more cases in the volume of work on the subject indicate the economic importance. The forms of endometritis can be classified according to the type and extent of discharge. They are: first degree (absent or intermittent); second degree (continuous mucopurulent); or third degree (purulent). It seems likely that the ratio of types is on the order of 6: 2: 1 from the first to third degrees respectively.

Most commonly found bacteria are the staphylococci and *E. coli* with nonhemolytic staphylococci predominating and hemolytic streptococci not much less common. *Corynebacterium pyogenes*, as a secondary invader, may be associated with 15 to 40 per cent of severe cases. Prognosis has usually been considered poor. Major emphasis in research work indicates that the second and third degree of metritis will be associated with hemolytic strains of *E. coli* and staphylococci. The prognosis has been found worst in high producing cows, which often prove resistant to treatment.

sulting in fetal starvation and death. The dead fetus becomes a foreign body and is expelled.

The survival of *Leptospira pomona* outside the animal's body seems to be related to the interaction of several factors including temperature, pH, moisture, the various constitutents of soil and water and the presence of naturally occurring microorganisms. Moisture was extremely important, these organisms survived from 30 minutes in air dried soil to 183 days in soil supersaturated with water.

Again, it has been pointed out that *Leptospira pomona* infection normally spreads through contamination of the drinking water with infected urine. Infection spreads rapidly through the herd. Certain research workers collected urine samples from 17 reactor heifers in an active outbreak of leptospirosis and found 10 urine samples positive to leptospirosis. Other research workers infected animals in late pregnancy to determine the influence of the infection on the pregnant animal. One animal aborted 19 days after infection. Another animal, 7 months pregnant, carried her calf to term. A third cow, 6 months pregnant, was infected and on day 13 required the use of caesarean section to deliver the calf. A fourth cow, 5 1/2 months pregnant when exposed to leptospira, aborted a well-developed dead fetus 20 days later. A sixth cow developed a more classic picture of leptospirosis, had a definite febrile response by the fifth day, positive leptospiral infected blood on the fourth and fifth day, and showed antibodies on the seventh day which reached a maximum antibody titer on day 25. Abortion occurred 47 days after infection. Degenerating fetal membranes were seen protruding from the vulva and by manipulation of the unbroken membrane the dehydrated fetus was removed through the cervix. Approximately 33 per cent of pregnant cattle exposed to field outbreaks of leptospirosis will abort.

In another outbreak of leptospirosis, more than a third of the cows developed fever lasting from 1 to 2 days followed by a decrease or cessation of milk production for 5 days. The milk secreted was watery and of varied color, depending partly on the presence of blood and sometimes resembled colostrum. Flakes and clots were usually present. The udder was soft and flabby with no signs of acute inflammation. The man attending this group of cattle also developed an influenza-like disease and was serologically positive. It was recently reported that infection of

cattle at or immediately preceding estrus would interfere with conception. It is believed the uterus is normally conditioned so that the semen can be propelled into the oviduct where conception takes place.

Vibrio infections can also be taken into the uterus and prevent conception by mechanical means or by inflammatory excitement. The major pathological changes observed by research workers in experimentally induced vibriosis were inflammation of the oviduct, inflammation of the lining of the uterus, and extensive generalized inflammatory edema of the fetal membranes.

One of the leading authorities on reproductive disorders suggests that these four cardinal points should be emphasized:

1. Are all of the cows examined daily for at least 15 minutes by one properly trained and interested in observing the animals for any abnormalities.

2. The importance of the type and quality of breeding records kept on the herd.

3. That the animals should be bred 60 to 90 days postpartum in order that any infection present at the time of parturition would clear before the animals were rebred.

4. The importance of knowing that the animals being purchased for addition to the herd were free of these diseases which could bring about lowered conception rates in the breeding herd. He stressed that animals declared to be free of infectious diseases should be specifically examined for brucellosis, leptospirosis, virus diarrhea, infectious bovine rhinotracheitis, pustular vulvovaginitis, listeriosis, and whether any histories were present which would indicate that certain fungi might have caused abortion.

There is no greater service that the veterinarian can render to the livestock producer than the establishment of a breeding control program of periodic examination of the genital organs of the cattle. The results of such a program are gratifying and financially rewarding. Results obtained compensate the owner three or four times the amount of the yearly fee. The maintenance of accurate records enables the producer to know his exact breeding status at all times so that he may plan his operation

There is a question about the importance of some of the vaginal infections as a cause of infertility in the cow or bull.

TRUE REPRODUCTIVE INFECTIONS

TRICHOMONIASIS

Trichomoniasis is seldom diagnosed in beef herds in Florida. Due to the importance placed on other factors that contribute to lower calf crops in many Florida beef herds, it is possible this disease is being overlooked. In states where surveys have been conducted to determine the incidence of trichomoniasis it has been found to be more common than suspected.

Trichomoniasis is an infectious contagious disease causing abortions, repeat breeding and pyometria in the female. The disease is confined to the genital tract and is caused by a protozoan parasite. It is a true venereal disease and is spread from infected to susceptible animals at the time of coitus. Transmission may also occur when contaminated semen is used artificially. Spontaneous recovery occurs in the female if a sexual rest period is allowed, but infected bulls, unless treated, may remain carriers for life. There are no clinical symptoms to indicate trichomoniasis infection in bulls. However, bulls exposed to infected females usually become infected. The trichomonads are confined to the prepuce and external parts of the penis. They may invade the urethral opening but rarely does the infection reach the secondary sex glands.

The laboratory procedures used for diagnosing the infection in bulls are microscopic examinations of washings or direct smears from the prepuce and culturing material from the prepuce. The former technique is used more frequently. In mild or prolonged infections several examinations may be necessary. When the organisms are found, a positive diagnosis can be made, but it may be necessary to breed a suspected bull to several susceptible virgin heifers and recover the organism from them before a positive diagnosis can be made.

Bulls may be treated successfully, but treatment is often impractical except when expensive animals are involved or certain blood lines are to be maintained. Treatment is time consuming, and the difficulties in determining an absolute negative status may make it uneconomical. Trypaflavine is the drug most com-

ly good results. However, treated bulls should be tested and proven negative before being exposed to susceptible cows.

Whether or not to treat infected bulls would depend upon certain circumstances. There would be no point in treating bulls that remain in infected herds. Re-infection would most likely occur since some cows remain carriers even though they breed and have normal pregnancies. From the knowledge that is available about the new vibrio vaccine, there would be little need to treat bulls that are to be used in vaccinated herds. Valuable bulls and bulls with desired blood lines which are to be bred to negative animals should be treated.

Systemic Infections

Organisms capable of causing systemic infection include bacteria, viruses, parasites, fungi, and others. After gaining entrance to the body and reaching the circulatory system certain of these microorganisms and/or their toxins may invade certain tissues of the reproductive system as well as other tissues of the body. When this occurs an inflammatory process generally takes place at and around the point of infection. The inflammatory process may result in temporary or permanent damage to certain tissues responsible for the development, storage, transportation, and nutrition of sperm.

Another factor associated with systemic infection which may affect reproduction is body temperature. Proper functioning of the testicles requires a temperature lower than the normal temperature of the body. High and prolonged body temperatures may affect the tissues where spermatazoa originate, as well as quality of mature sperm. There may be a decrease in the number of sperm produced and an increase in the number of morphologically abnormal spermatazoa. High body temperatures may also decrease longevity of mature sperm, resulting in a high percentage of dead spermatazoa and a reduction in motility.

The same effects may be produced in bulls subjected to prolonged high external environmental temperatures not associated with systemic infections. A further factor associated with systemic infections which may influence the bull's ability to breed is weakness resulting from the debilitating effect of the infection and possible loss of libido.

BRUCELLOSIS

Brucellosis, commonly called Bang's and contagious abortion, is a systemic disease affecting reproduction. It is caused by the organism Brucella abortus. Natural infection occurs most commonly through ingestion of food, water, and other materials contaminated with brucella abortus organisms. Infection may take place, but not likely, through skin abrasions and the mucous membranes of the eyes and nose. Infection in the cow may also occur from artificial or natural service with infected semen. The organism, after being ingested, enters the blood stream and from there localizes in some part of the body. In the cow it is generally the uterus, lymph nodes, and udder; in the bull, the testicles, secondary sex organs, and joints. For some unknown reason bulls appear to have more immunity against brucellosis than cows. However, some do develop the infection. When infection does occur it frequently localizes in the reproductive system and may be shed in the semen. Visible symptoms that may be suggestive of brucellosis infection in the bull are limited to swelling of one or both testicles and surrounding tissues. Occasionally infection will localize in a joint causing inflammation and swelling. These symptoms are not specific for brucellosis but when observed in the bull, brucellosis should be suspected. As in the cow, the blood agglutination test is the most widely used diagnostic method of determining infection in the bull. This test identifies infection regardless of where the infection may localize. A semen agglutination test may be used to determine localization in the testes or other sex glands. There is no treatment for brucellosis infection in cattle. Positive animals should be removed from the herd and slaughtered immediately following identification of the infection.

LEPTOSPIROSIS

Bulls may become infected with both the mild and acute forms of leptospirosis. The disease is not considered a reproductive disease. However, pregnant cows that become infected with leptospirosis may abort. The severe form in bulls may cause a temporary decrease in normal spermatazoa production due to the fever and debilitating effect of the infection. The primary concern regarding bulls that are sick or have recently recovered from leptospirosis is the possibility of spreading the infection in

their semen and urine. Infective leptospirosis organisms are shed in the urine for several months following recovery from symptoms of infection. Since semen is ejaculated through the urethral opening, infection may be transmitted in this manner.

INFECTIOUS PUSTULAR VULVOVAGINITIS

Infectious pustular vulvovaginitis (IPV) is caused by a virus. The disease is reported as being the venereal type of infectious bovine rhinotracheitis (IBR) infection commonly known as Red Nose. Primary lesions of IBR occur in the upper respiratory tract, while those of IPV occur in the vagina of the cow and the penis and prepuce of the bull. The two infections are thought to be caused by identical viruses. IPV has been described under different names, coital exanthema probably being the most common, others being vesicular vaginitis and vesicular venereal disease. Principal symptoms in the bull are pustules, ulceration, and severe inflammation of the penis and prepuce. Barring secondary infection recovery is spontaneous in a few days to several weeks. However, scar tissue causing strictures and adhesions may occur during the healing process of the affected tissue. There is no effective treatment against the virus. Antibiotics and other types of medication are beneficial in curtailing secondary infection.

It is generally thought that IPV does not affect semen production, but bulls may refuse to mount while active lesions are present due to pain. Occasionally, permanent inability to breed naturally may occur because of adhesions and strictures.

GRANULAR VENEREAL DISEASE

Granular venereal disease is sometimes called infectious vaginitis, granular vaginitis, and nodular vaginitis. A cause for the condition has never been positively identified, and experimental transmission has been unsuccessful. Some authorities think the disease is universally distributed and that almost every cow has the disease at some time during her life.

In the bull, the lesions are confined to the penis and sheath. In mild infections, blister like lesions occur on the mucous membranes. In severe cases in addition to the above mentioned lesions the mucous membranes become inflamed and there may be a purulent discharge.

Normally recovery occurs in three to four weeks in cows, but

may take several months in the bull. If the lesions are extensive enough, bulls will refuse to service cows.

NONSPECIFIC INFECTIONS

Infections of the reproductive organs of the bull may be caused by organisms other than those associated with specific diseases. These may include certain rickettsia, viruses, fungi, different types of internal or external parasitic conditions, and bacteria such as streptococcus, staphylococcus, corynebacterium, paseurella, and many others. Temporary or permanent infertility may occur as a result of inflammation, abcess formation, adhesions, degeneration, or other pathologic changes that might be caused by infection with these organisms. Also these organisms may be transmitted to the female by natural or artificial breeding.

Only a limited number of conditions which may affect reproduction in the bull have been mentioned here. Others that we have not mentioned are endocrine imbalances, nutritional, parasitism, congenital defects, inherited traits, psychic and traumatic conditions. I would like to say in closing that frequently there is a relationship between some of these conditions and the susceptibility of bulls to some of the infectious diseases which we have mentioned in this paper.

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C. B. PLUMMER, JR.

Checking Bulls for Breeding Soundness

Checking bulls for potential breeding soundness has become a routine practice on many livestock farms. Surveys indicate that approximately 10 to 12 per cent of the bulls tested are either questionablé or unsatisfactory potential breeders. This percentage seems to be rather consistent where surveys have been conducted. To some people here in Florida, one out of ten or twelve bulls may not seem exceptionally high when we consider that three or four cows out of ten, on the average, do not calve each year.

Where 12 to 15 bulls are used to service 300 cows on improved pastures under fairly close confinement, the loss in bull power because one or two of the bulls are unsatisfactory is not too critical. However, on large ranges where small groups of cattle tend to band together, and in small herds where only one or two bulls are used, the calf crop may be nil or very low if an unsatisfactory bull is used. Another factor for consideration is the investment and upkeep on an animal that has little or no chance of making a financial return.

Prior to 1952 very few range bulls were being evaluated for breeding soundness. It was not until the late 1940's that a practical method for collecting semen became available. Also prior to this time there was no uniform or standard criteria being used for evaluating semen from bulls used for natural service. Today there are several models of electroejaculators which make semen collection possible and practical, and a standard set of criteria is now being used to evaluate semen.

About 1950, a group of research veterinarians at Colorado

State University along with practicing veterinarians in Colorado and surrounding states formed an organization to assimilate information and develop standard procedures for determining the potential breeding soundness of bulls to be used for natural service under range conditions. Through data supported by research, as well as reasoning, and personal experience from testing several thousand bulls standardized techniques and criteria were developed. Through short courses and schools conducted by this organization, many veterinarians throughout the United States are now using this method for evaluating a bull's potential ability to breed and settle cows.

Generally, testing bulls for breeding soundness is done for two reasons. One, the producer wants to be reasonably sure that the bull to be used during the coming breeding season is capable of settling on first service a high percentage of the fertile cows he breeds and, two, to determine the potential breeding status of bulls for sale or purchase.

The evaluation of bulls for potential breeding soundness is based on two factors: semen quality and physical traits. The correlation and wise evaluation of all factors found on a careful physical examination and semen test is essential because certain standards must be met in each area before a bull can be classified as a potential satisfactory breeder.

live and dead spermatazoa in the sample. Each criterion is divided into letter grades: (1) VG=very good; G=good; F=fair; and P=poor. Each grade is assigned a numerical score and when added together gives the total semen score. The percentage of the total score arbitrarily assigned to each grade is based on the importance of each criterion used in the overall evaluation of semen. For example, in the two top grades, very good and good, vigor receives the highest percentage of the total score, morphology is second, concentration and per cent alive third, and fourth respectively. In the two lower grades, fair and poor, concentration is given a higher value than vigor or morphology.

Three classifications are used for designating potential breeding soundness. They are: (1) satisfactory prospective breeder, (2) questionable prospective breeder, and (3) unsatisfactory breeder. Bulls placed in the satisfactory prospective breeder group are physically fit and have a semen score of 60 or above. Bulls meeting these requirements are considered to be capable of settling on first service not less than 50 per cent of the fertile cows to which they are bred.

Bulls are placed in the questionable prospective breeder classification for several reasons. They are: (1) when there is a question as to whether a truly representative sample of semen has been collected for examination, (2) when semen scores range between 59 and 30, and (3) when there is a question regarding recovery from a physical defect. Some bulls in this group may change for the better while others degenerate further. In most instances, questionable bulls should be rechecked at a later date. Bulls in this classification would be expected to settle a few cows, but the conception rate would probably fall well below 50 per cent on first service.

Bulls classified as unsatisfactory breeders have obvious physical defects with little or no chance for recovery and/or a semen score of less than 30.

This method of testing and evaluating bulls for breeding soundness is not infallible, but it does, however, provide a guide and facilitates standardization of techniques for examining and evaluating bulls for potential breeding soundness. It also affords a more accurate means for recognizing and recording changes in semen quality that may occur between two tests conducted by different veterinarians or between tests by the same veterinarians.

We were asked to discuss costs for examining bulls for breeding soundness. We will not attempt to say what the fee should or should not be. Nor will we imply that the fees mentioned here are those that will be charged by a veterinarian. Ten dollars is the common fee charged by veterinarians in Florida and throughout the United States who use the standardized techniques we have just described. However, fees ranging from $5.00 to $15.00 per bull have been reported.

In Florida, the $10.00 fee per bull generally includes the trip cost if ten or more bulls are tested on one trip. If less than ten bulls are involved, an additional fee for the trip will probably be charged. When deemed advisable by the owner and veterinarian that questionable potential breeders be rechecked at a later date, *the original $10.00 fee includes the rechecking but does not* necessarily include the trip fee. This is a detail that should be worked out at the discretion of the owner and veterinarian.

In summary—evaluating bulls for potential breeding soundness is another tool available to cattle producers for improving and maintaining calf crop percentage. When the test is conducted by a qualified person using the accepted standard procedures as outlined above the producer can be reasonably sure that for the current breeding season, the bull classified as satisfactory will be able to settle on first service, at least 50 per cent of the fertile cows to which he breeds. The test also helps eliminate maintenance and other costs associated with unsatisfactory and sometimes questionable bulls for which there is little or no possibility of making a return on investment.

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C. L. CAMPBELL

Interstate Disease Control Regulations

Frankly, I cannot think of many topics other than those involving pure statistical data which are more capable of boring an audience than those of citing regulations. The "dos and don'ts" —or perhaps it is better expressed by the "can'ts and cans" involved in the transportation of livestock appear as a maze so complicated to the average producer as to be incomprehensible. And, naturally, the "can'ts" always outnumber the "cans." Try as one may to break the subject down into A, B, C language, it is most difficult for the majority of species of livestock. This is particularly true of cattle.

This confusion is due in large part to the fact that these regulations which are drawn up basically in complicated veterinary terminology must be framed in the vernacúlar of the legal profession as well as for the purpose of withstanding the onslaught of attorneys when challenged in the courts of our nation.

So, I am not so sure that anyone—the producer or shipper, the veterinarian who issues the health certificate, the lawyer who defends or challenges the laws under which they are promulgated, or even those who interpret or enforce them—fully understand in all instances the original intent of the various regulations. They often differ considerably in language from what they contained when first proposed.

Frequently it appears the regulations are so complex that they tend only to defeat their designed purpose. As such, they are subjected to considerable ridicule and abuse. It must be remembered, however, that these interstate regulations were promulgated and adopted for the purpose of protecting the health

of the state's livestock industry by public spirited producers who conscientiously felt they were doing the right thing in the interest of the entire industry. If accepted in this light and in a spirit of cooperation, interstate regulations, as complicated and controversial as they may seem, serve a most useful purpose—that of assuring a continued healthy livestock industry.

In order to get the proper insight on this complex problem, perhaps it would be well to present some background on the reasons for having them and the methods of developing interstate health regulations on a national and state level.

Each state has the right to enact laws and promulgate regulations for the admission of livestock. Further, it is the prerogative of the individual states to set forth and to define policies and procedures in their attempts to prevent and to control transmissible diseases of animals. In fact, if the livestock industry of a state is to survive it is mandatory that producers and regulatory officials adopt and rigidly enforce such health measures as are necessary to assure this.

The control of contagious or transmissible diseases or their prevention thereof serves a dual purpose; primarily, to protect the public health; secondarily, to protect the economy of the industry. It is an established fact that the livestock industry is the keystone of the arch of agriculture which, if it is to remain profitable, must continue to remain healthy.

Each livestock regulatory official is charged with the responsibility of enforcing those laws and regulations which serve to prevent, control, and eradicate dangerous transmissible diseases of livestock. It is the responsibility of the producer whose interest he serves to insist that such mandates be carried out. In so doing, a static or receding disease incidence may be maintained, and the introduction of exotic diseases which are potentially disastrous to the industry can be minimized.

Interstate regulations should foremost and specifically be designed to prevent and to control transmissible diseases, and should never be promulgated unless and until they become necessary from a disease prevention and control standpoint. Otherwise, there will be laxity in their enforcement. They will tend to be disregarded by the importer, and will serve merely to "clutter the books."

Now let us take a look as to how these regulations come about. They do not just happen without a need to begin with.

Sixty-nine years ago a group of men assembled in Fort Worth, Texas, from several states in an attempt to solve the problem of some diseases which cattle were spreading along their route of travel, from the Southwest to the marketing centers in the midwestern section of the nation. Then, as now, livestock producers of this country were faced with problems of overcoming economic losses occasioned by infectious and contagious diseases. Looking back in retrospect, from our years of experience, we might view the enigma of cattle fever tick and scabies eradication as minor when compared to the problems and losses confronting the livestock industry today. These, however, were the first matters with which this group was concerned. This group has grown immensely and is now known as the United States Livestock Sanitary Association. This body, composed of livestock and regulatory people from each of our states and with membership from throughout the world, meets regularly to discuss livestock health problems. They work out and eventually formulate guidelines on policies and procedures in controlling and eradicating diseases across the nation in the form of recommendations to industry groups. Since its organization in 1897, this association has endeavored to correlate scientific information, sound thinking, and practical experience in infectious livestock disease control. They have become the agency which, through the years, has been primarily responsible for formulating and conducting livestock sanitary disease control programs necessary to effect a profitable livestock industry and maintain a balanced agricultural economy. How long the association remains the effective agency it has been in the past will be determined by the manner in which it meets and solves the problems continuing to confront it yearly.

In many areas of disease control the recommendations of this group can be accepted by all states, thereby establishing criteria by which certain diseases may be effectively controlled with a minimum number of problems. This is not true, however, in the establishment of uniformity in laws and interstate regulations for most species of livestock. With cattle it has seemed almost an impossibility to adopt uniform regulations wherein they could be transported into all of the states under the same testing or certification procedures. For instance, and speaking of cattle only, each state, or at least group of states within a given area, is interested in certain phases of production, such as raising

grazers or feeders, dairy cattle or purebred breeding cattle—and the laws of these particular states are enacted to best serve these interests. Likewise, the interstate regulations of each state are designed primarily to protect the phases of livestock production common to that state.

Even within the industry of a given state there are conflicting interests. Factors vital to the development of the industry in one state may be of little importance in another. Livestock disease control programs which exactly fit one state or area may seem unnecessarily stringent or entirely inadequate in another.

In spite of these variances there has been an intense desire throughout the nation to achieve uniformity in these regulations. In reviewing the proceedings of the United States Livestock Sanitary Association for each of the past twenty-five years it is apparent that this is gradually being brought about. Perhaps in another twenty-five years this will be achieved.

The cattle disease area in which there is the greatest diversity

Were I to attempt a discussion of the requirements of all states it would take too long. There is a 300 page booklet available with a compilation of those requirements for all states.

All cattle consigned to Florida for any purpose other than for immediate slaughter at approved establishments, or feeder steers held isolated at their destination, must be accompanied by an official health certificate issued by an approved veterinarian in which he sets forth sworn data on the cattle contained in the shipment. This certificate is a legal attestation that the veterinarian signing it has conducted the necessary examinations and has found the animals free of infectious communicable diseases. An improperly prepared health certificate or one which is issued without the shipment being in full compliance with the requirements of the state of destination is not only worthless, but subjects the seller and buyer to possible prosecution for violation of interstate shipping regulations. Furthermore, it jeopardizes the accredited status of the veterinarian which would preclude his participation in any of the official programs of the state or federal government.

All vehicles transporting cattle into Florida for any purpose must be cleaned and disinfected under approved veterinary supervision and so certified by him. No cattle infested with or exposed to cattle fever ticks, scabies or screwworms shall be imported into the state for any purpose. Apparently healthy cattle of strictly slaughter type to be used only for immediate slaughter may be imported into Florida without health certificate or negative brucellosis and tuberculosis tests if consigned to approved slaughtering plants and killed within ten days after arrival. Steers for feeding purposes may be imported without a health certificate or negative tests provided they are maintained at a destination separate and apart from dairy and breeding cattle. These are the relatively simple parts of Florida cattle import health requirements. The tuberculosis requisites are not quite that simple, but really are not too involved.

TUBERCULOSIS

Cattle may be imported into the state without an additional tuberculin test provided they are identified on official health certificates as originating in: (1) tuberculosis free accredited herds; or (2) qualified negative herds from modified accredited tuber-

culosis free areas wherein all cattle in the herd have passed negative tuberculin test within twelve months prior to entry. Cattle imported must have been part of the herd at the time of the last herd test.

Cattle including steers from herds not under quarantine for tuberculosis may be imported without tuberculin test provided they are consigned to a state-federal approved stockyard. All such cattle except steers sold for consignment to premises wherein they are maintained separate and apart from dairy and breeding cattle, and animals sold for consignment to recognized establishments for immediate slaughter, must pass negative tuberculin test at the stockyard prior to sale or before leaving the stockyard. In the case of cattle not completing tuberculin test prior to sale, such cattle must be penned in facilities separate and apart from other cattle and may be sold through regular sales ring after sale of all other cattle has been completed. This is provided, however, that tuberculin test will not be required on cattle for other than dairy purposes imported under this subsection which originate in areas in adjoining states within a radius of twenty-five miles of the state-federal approved stockyard to which they are consigned.

Cattle not meeting requirements of paragraph (A) or (B) above may be imported into the state provided they originate from herds not under quarantine for tuberculosis and have passed negative tuberculin test within 30 days prior to date of entry.

Steers from herds not under quarantine for tuberculosis may be imported without tuberculin test provided they are maintained separately and apart from dairy and breeding cattle.

All cattle imported into Florida for dairy purposes are subject to retest for tuberculosis not earlier than 45 days nor later than 60 days after entry into the state.

At the present time we are operating under a set of brucellosis import requirements that are antiquated with respect to the progress which is now being made on eradication of this disease from both a state and national standpoint. Recently the Florida Animal Industry Technical Committee (formerly the Florida Livestock Board) considered, in consultation with official representatives of Florida's cattle and dairy associations and allied industries, a set of streamlined regulations which would not only be in keeping with the pace which we are setting with brucellosis elimination, but which will also bring about greater uniformity

in our requirements with those of other states. Anticipating that these will probably be formally signed and adopted by the Florida Commissioner of Agriculture within the next month, and by the time this book is published, I will discuss these rather than existing brucellosis import regulations.

BRUCELLOSIS

Cattle for dairy and breeding purposes must be accompanied by an official health certificate and must meet one of the following requirements:

1. Cattle originating in an individually certified brucellosis free herd, certified brucellosis free area, or modified certified brucellosis area must be negative to official brucellosis blood test conducted within 30 days of the date of entry. Calves under six months of age and official calf vaccinates under 30 months of age which are not parturient or post parturient are exempted from the brucellosis test requirement.
2. Cattle officially vaccinated against brucellosis, between the ages of four and eight months, must be accompanied by certificate or record of vaccination issued by the chief livestock sanitary official of the state where the animal was vaccinated. Official vaccinates over 30 months of age and those under 30 months of age which are parturient or post parturient must be negative to official brucellosis blood test conducted within 30 days of the date of entry. Bulls vaccinated after April 15, 1964, will not be considered as official vaccinates.
3. Cattle originating in certified herds or herds not under quarantine for brucellosis in certified brucellosis free areas or modified certified brucellosis areas may enter the state without brucellosis test provided they are consigned to a state-federal approved stockyard. Such cattle sold for other than immediate slaughter must have negative brucellosis test before leaving the stockyard.
4. Cattle over 6 months of age not meeting the requirements of sub-paragraph 1, 2, or 3 above must be negative to an official brucellosis blood test conducted within 30 days prior to the date of entry. Special permit must be obtained from the state veterinarian of Florida prior to the shipment of cattle. Cattle permitted under this sub-paragraph must be isolated at destination for a period of 30 days and tested for brucellosis at the end of

the isolation period. Cattle not negative to this test must be disposed of for immediate slaughter.

5. Calves under six months of age must be covered by official health certificate showing that they originated in negative herds under federal-state supervision.

Cattle for feeding purposes must meet the following requirements:

1. Steers may be imported without health certificate, vaccination certificate, brucellosis, or tuberculosis test provided they are maintained separate and apart from dairy and breeding cattle.

2. Bulls and female cattle of recognized beef type from herds not under quarantine may be moved to feed lots designated and approved by the Florida Department of Agriculture wherein cattle are maintained separate and apart from dairy and breeding cattle without vaccination certificate, brucellosis or tuberculosis test, provided they are accompanied by a special permit from the state veterinarian of Florida.

The request for permit required by this section shall include the name and address of the consignor, the number of animals to be shipped and the exact place of origin and destination.

All cattle moved into the state under this section shall be accompanied by a certificate issued by a federal or state inspector or an accredited veterinarian showing the name and address of the consignor and consignee, breed, age and number, and that the cattle have been electrically or otherwise hot branded with the letter "S" not less than two inches in height conspicuously displayed on the left jaw, and that such cattle are being moved for feeding purposes.

Cattle moved into Florida in accordance with this section shall be held on the premise of destination, segregated from dairy and breeding cattle, and may be moved only for immediate slaughter to a recognized slaughtering establishment.

Cattle moved into Florida in violation of this section shall be immediately consigned to slaughter at a recognized slaughtering establishment, and such violation shall subject the feed lot to revocation of its status as a designated and approved feed lot.

Apparently healthy cattle of strictly slaughter type to be used only for immediate slaughter may be imported into the state without health certificates, negative brucellosis or tuberculosis

test, provided such cattle are consigned to recognized slaughtering establishments within the state. Such cattle shall be slaughtered within 10 days after arrival at destination.

All tests for brucellosis required under this section shall be conducted in a state or federal laboratory.

Livestock regulatory officials in carrying out their duties are at times criticized by livestock men and dealers for causing, what seems to them, unnecessary interference in the free movement of their animals. However, without the support of the herd owner, cattle dealer, veterinarians, and other participating agencies in preventing and controlling diseases, regulations designed to obtain desired results will fail. Honesty, integrity, and efficiency on the part of all who participate in the breeding, raising, selling, testing, certifying, or otherwise handling of livestock, makes for confidence between the seller and buyer and regulatory officials. This is essential to a healthy and profitable livestock industry and the free movement of livestock between the states.

and fertility in bulls, therefore the breeding season should be controlled in both length and time. A short breeding season also allows calves to be born ahead of the period of maximum forage quality and quantity so cows will be on the best forage during the breeding season. This provides the best environment for the cow to return in heat following calving and also is at a time of lowered temperature so the bull will be at maximum fertility.

In areas of high summer temperatures, natural shade should be provided whenever possible as a protection from solar radiation as well as to reduce atmospheric temperature. If natural shade is not available, artificial shades can be built to give similar protection. Studies at the Louisiana Station have shown increased calf gains up to weaning time in cows having access to shade during the summer months.

A program of disease control should be followed in all herds for maximum fertility. One of the best practices is to vaccinate all replacement heifers between four and eight months of age with brucella vaccine to immunize against brucellosis. All purchased bulls should be checked for the various reproductive diseases before purchase to avoid introduction of disease into a clean herd.

Fertility can be improved by culling females which do not become pregnant and selecting replacement heifers from cows and bulls with a record of high reproduction. It is a good plan to cull all heifers not pregnant after the first breeding season, thus eliminating heifers with permanent anatomical or physiological barriers to reproduction. Also, this is a good economic practice since such two-year-old heifers are usually fat and bring a good price. By selling such nonpregnant heifers in the fall the cost of wintering a non-producing female is saved. Where the reproduction rate is very low, cows that wean a calf in the fall but are not pregnant may have to be held over for the next breeding season. However, such cows should be identified so they are automatically culled after they fail to become pregnant at another breeding season. By following the above program at the Beef Research Unit near Gainesville, Florida, the pregnancy rate increased from 42 per cent in 1953 to 93 per cent in 1963. As the pregnancy rate increases above 80 to 85 per cent, all nonpregnant females should be culled and replaced by saving additional numbers of replacement heifers.

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E. J. WARWICK

Future Beef Cattle Breeding Programs

Those of us who have the temerity to give speeches about the future—and especially those of you who listen to such speeches—should start by reminding ourselves that predictions are almost never fulfilled in their entirety. Perhaps only rarely are they correct in broad outline.

Before going any further, I want to stress that the opinions expressed here are completely my own. In no manner should they be construed as official predictions of the United States Department of Agriculture.

For the most part, we can only examine present trends and assume they will continue.

This assumption can be dangerous, and I can draw upon my own experience for a shining example of this fact. In the fall of 1936, just over 31 years ago, I took my first university course in agricultural economics. In it we were told that the population of the United States would increase rather slowly, reach a peak of about 150,000,000 in the early 1950's and thereafter trend downward. The error made was that of assuming the low birth rates of the depression years of the early 1930's were a permanent characteristic of the population of the United States.

To make predictions about future trends in beef cattle breeding, we must perforce make some predictions about the characteristics of the country we will be living in as the future rolls by. This will certainly be an important influence, perhaps the most important one, on the kinds of cattle we will need and the kinds of breeding programs we will use to produce them most effectively.

Recent careful studies (Landsburg, 1964) led to average population predictions of 245 million by 1980 and 330 million by the year 2000. Minimum and maximum predictions for the year 2000 were 270 and 430 million. We will have to accept these projections with some reservations, just as I think we should have in 1936. However, they are undoubtedly more soundly based than those of 30 years ago.

Let us assume that the average of the population projection proves to be the case. It then appears that the American person can continue to have 100 pounds of beef per year to 2000 or thereabouts. This assumes moderate improvements in crop yields and in efficiency of livestock production. With these, it should be possible for us to maintain present general production methods, utilizing large amounts of concentrates for cattle finishing. Actually, there will probably still be a land surplus, with correlated crop surpluses, past 1980. By 2000, land availability is likely to be a bit under need. A probable resulting tendency will be emphasis on beef production from forages. After that, competition for concentrate supplies is likely to become keener. The future of the beef industry will be a bit uncertain.

It is thus apparent that in discussing the future we will have to specify which future we're talking about. The immediate future, i.e., the next 15 or 20 years, may see one set of trends. The intermediate future of the next 35 to 40 years may see inception of a new set of trends. The long-range future may present quite a different picture. Of necessity, we will talk today mostly about the immediate and intermediate futures.

Quite a bit of what I will say is speculation about things which *could* happen. Actions taken by cattlemen, especially seedstock producers, will have a lot to do with whether or not they *do* happen.

Logically, we can't separate our predictions about trends which may occur in breeding practices in seedstock and in commercial herds. They are very much interrelated. However, for convenience we will attempt to look at them separately.

First, what are some likely trends in breeding practices of commercial herds?

1. Acquisition of sires or semen on basis of predicted or proven ability to sire offspring with maximum inherited potential for producing a quality product economically.

Briefly, this means that sires will be selected on records—

their own and those of the strains, lines, or families from which they come.

The rate at which this occurs for a species seems to be directly related to the generation interval and reproduction rate. Crop breeding was almost wholly converted to the basis of records 30 years ago, in poultry the conversion was essentially completed 20 years ago and the conversion in swine is well underway. Because of the ease of measuring performance in dairy cattle, and in spite of their slow reproductive rate, the conversion is far along. Beef cattle are behind, but I look for the conversion to be nearly complete by 1980.

It is further along already than many realize. From a standing start in 1953, over 400,000 cows were in organized performance testing programs in 1964.

This by no means indicates that the human eye will be completely replaced as a tool in making selections. Wheat and corn breeders still use the eye to pick out the individuals or lines subject to lodging.

It does mean that the use of the eye will be geared to evaluate economically important characters—particularly potential carcass yield. The observations will be made systematically and they will become part of the records.

However, present useful objective measures of performance and potential carcass quality will be improved and are likely to replace "eye ball" judgment to an ever increasing extent.

We have put this discussion of records under the heading of commercial production. Actually, not very detailed individual records will be kept in commercial herds. The seedstock man is the one who will keep the records—under the pressure of commercial men—for sires that will do the job in their herds.

2. Increased use of artificial insemination (A.I.). Present techniques are making this practical in many commercial herds. Even if no advances are made in A.I. techniques themselves, use of the process in commercial herds will increase. This will be because elevated levels of management, inevitable in the quest for increased efficiency, will permit effective use of A.I. in more herds. Further, it is almost a foregone conclusion that further research will improve A.I. techniques and make them applicable to more herds.

I am sure we all believe that efficient production and quality of product are under genetic control. If this is true, then use of

the top 3 to 5 per cent of all sires will on the average produce offspring superior to the average of those that would be sired by the top 50 to 75 per cent of *those produced in seedstock* herds.

This is the basic fact which will make A.I. increase. It will be equally true no matter how much seedstock herds improve.

How fast will use of A.I. increase in commercial herds? No one can now forecast this accurately. Practical difficulties make it unlikely that the increase will occur overnight. However, it is not unlikely that by 1980, 35 to 50 per cent of beef cows will be artificially inseminated. The percentage of commercial beef cows artificially inseminated is now slightly greater than it was for dairy cows in 1945. About 45 per cent of dairy cows are now artificially inseminated. Thus, the increase projected for beef cows is comparable to that attained in dairy cattle in the past two decades.

The commercial industry in many parts of the nation today is based on production of high grades, i.e., breeding generation after generation to bulls of a single breed. Obviously, after a few generations of breeding commercial cows to the best bulls of a breed through use of A.I., the best bulls produced in commercial herds would be as good as those in seedstock herds. There are those who fear that these bulls will be used and that A.I. will destroy the seedstock industry. This could happen, but I believe two things will prevent it. First, we will see increasing specialization. As a result, economics of production will tend to preserve the seedstock herds. Second, the next item to be discussed will effectively stop selection of commercial bulls from commercial herds themselves.

3. Increased exploitation of hybrid vigor.

In most cases this will mean crossbreeding. This is nothing new to Florida cattlemen. However, in many parts of the country it is looked upon as a radical idea.

We don't have the time to make a detailed review of current research on the subject. In essence, however, a clear picture is emerging. Properly designed crossbreeding systems have the potential of increasing efficiency of production from 5 to 15 or even 20 per cent as compared to the average of purebreds by the same parents. A high proportion of the increase is due to higher reproductive rates and lower calf death losses. These characters do not respond easily or rapidly to selection for improvement.

Admittedly, there are practical difficulties to maintaining systematic crossbreeding systems under practical commercial conditions. However, they can be overcome by informed management. They are made easier by artificial insemination. A given cow can be inseminated with semen from any breed of bull desired as she comes through a chute. Separate breeding pastures for each breed of bull are not required.

Concepts may change, but from what we know now, it appears that bulls from pure breeds or lines will be needed in breeding systems which maximize hybrid vigor. In a commercial industry based on crossbreeding or line crossing, it is extremely unlikely that maximum productivity could be attained by using bulls produced in commercial herds for the next generation.

Thus, there will be a continuing need for top-quality sires. This should effectively halt any tendency for the commercial industry to also take over the functions of the seedstock industry under widespread use of artificial insemination.

4. Increased selling of slaughter cattle directly or indirectly on a carcass grade and yield basis.

You may well say that this is an economic or sociological question. I would be the first to agree. However, it is already occurring and further increase seems inevitable. The recently announced official adoption of an optional U.S.D.A. "cutability" grade will probably serve as a spur to selling slaughter cattle on the basis of true carcass value.

Sale of slaughter cattle strictly on the basis of actual or potential carcass value will affect breeding practices through speeding up trends toward specification buying. Commercial producers will have to produce kinds demanded. This will intensify demand for sires with predictable breeding behavior.

Remember I said earlier that we couldn't really separate breeding problems and predictions neatly into those affecting commercial producers on the one hand and seedstock breeders on the other? The foregoing discussion on commercial breeders pretty well proves this. I had to talk about seedstock breeders in it about as much as I did the commercial producer himself.

Let us try though to forecast now some of the likely future developments in the seedstock industry:

1. A reduced proportion of the nation's total cow herd will be in seedstock herds.

Two things make this probable. The first of these is art-

ficial insemination. With its growth, proportionally fewer commercial bulls will be needed.

The second is that even now we may have more breeding cows in seedstock herds than are needed for the economic welfare of the industry.

To develop this point let us assume all cows, commercial and seedstock, are bred naturally. Assuming 25 cows bred per bull each year, about 1,280,000 bulls would have to be in service to breed the nation's approximately 32,000,000 beef cows. If bulls averaged a useful life of three years, about 426,000 new ones would be needed each year. We can further assume an 80 per cent calf crop and a 50:50 sex ratio in seedstock herds. Thus, if all bulls raised were used, it would require about 1,066,000 cows to produce the needed bulls. If one-fourth of the bulls dropped in seedstock herds are culled, then about 1,419,000 cows would be needed.

You may argue that more than one-fourth the bulls born in seedstock herds should be culled rather than sold for breeding purposes. With natural mating it is difficult to visualize prices of bulls for use in commercial herds being high enough to permit a man depending upon bull sales for his major source of income to cull more and still cover his overhead and operating costs.

With increased use of artificial insemination, premiums for truly outstanding bulls may increase to the point where it might be economic for seedstock breeders to raise large numbers of bulls with the expectation that only the top 3 to 5 per cent will be used as breeders. The remainder, if well fed after weaning, will produce very desirable carcasses at 12 to 14 months of age. This procedure would give intense selection differentials for those used for breeding.

No one knows how many purebred, registered cows are now alive since records are not kept. About twelve years ago, each of the beef breed secretaries kindly gave me his best estimate for his breed. The estimates totaled to over 2,000,000 then. Probably numbers have increased since then.

Thus, it would appear that we may even now have more purebred cows than we really need.

If this be true, what are some possible reasons? Two major factors are the glamour of the purebred business and the related more or less continuous influx of outside money. This seems to include both that coming from wealthy persons to whom profit

is no object and from "little people" who invest in purebred females in the all-too-often forlorn hope of reaping a profit in the face of heavy odds.

Whatever the reason, future specialization of the seedstock industry is likely to act as a brake and keep numbers down to those actually needed for efficient commercial bull production. This number will depend upon level of bull prices and the intensity of culling which is economically feasible.

2. Individual seedstock herds will be larger and more specialized.

This has happened in crop breeding and in poultry breeding as emphasis on records has increased. It appears inevitable that the need for technical know-how to carry on breeding programs of the future will lead to larger units.

3. Selection will be directly for traits related to economical production of a quality product in commercial descendants of seedstock herds.

This will likely take many forms which we do not have time to discuss in other than broad outline here. They will likely include: (a) maintenance of breeding herds in commercial-type environments similar to those in which their commercial descendants will be expected to perform; (b) direct selection for highly hereditary traits under simulated commercial conditions including both pasture and feedlot; (3) selection for potential carcass quality by use of ultra sound and other devices which "look under the skin;" and (d) progeny testing of prospective herd sires on commercial herds through artificial insemination as a means of final herd-sire selection. These progeny tests will also be highly useful as checks on progress being made in selection for both production and carcass traits and as a check on combining ability of the herd or line with cows of the crossbred types to which bulls from the herd will be bred commercially.

Obviously, this will be a highly technical operation. Selection in different breeds or lines is likely to be for specific characters which that breed or line is expected to bring to a specific cross-breeding program.

4. Breeding will tend to be on a within-herd or closed basis with new bulls being introduced only after thorough preliminary progeny tests.

Ultimately, rather highly inbred lines may be formed to obtain more heterosis and precisely controlled specific combining ability

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Summary and Conclusions

The material in this book includes the reports presented by speakers at the Fourteenth Annual Beef Cattle Short Course held at the University of Florida in 1965. The program was designed to summarize the many factors which affect the calf crop with beef cattle. This summary will present only some of the highlights of the papers contained herein.

The substantial investment required per beef cow unit and the recurring yearly operating cost make it very important for one to obtain as high a calf crop as possible. In discussing the calf crop one should figure it on the number of calves weaned and the number of cows exposed to the bull in a given 12 months period. The aim of all cattlemen is to get as close to a 100 per cent calf crop as possible.

Many factors affect cow productivity. These include feeding, nutrition, breeding, management, environment, diseases, age of the animal, as well as other factors. The causes for low calf crops appear to be about the same in various regions of the country. Reproduction rate varies somewhat in different regions of the U.S. The variation which exists within each region, however, is about as great as that encountered between different regions. Considerable difference in calf crop can be obtained on practically adjoining ranches because of differences in management. Thus, a discussion of the factors affecting the calf crop is very similar and is applicable to all areas of the country. High calf crops can be obtained in any state or area of the U.S. by following good production and management practices.

Following are some factors which influence the calf crop:

1. *Underfeeding of cattle will result in a low calf crop.*

A low level of energy intake will delay the first heat period. If the level is low enough, it will stop estrus from occurring.

A low level of protein intake will also delay first heat, but this may be the result of decreasing appetite and thus decreasing the amount of feed the heifers consume. Thus, a lack of energy is as important as a lack of protein in decreasing reproduction rate. If the protein level is low enough, it will also cause estrus to cease.

A lack of vitamin A, phosphorus, copper, cobalt, and iodine have been shown to adversely affect the calf crop. Undoubtedly, a lack of or excess of other nutrients may also affect reproduction rate.

Florida studies have shown that underfeeding of bulls will affect their ability to reproduce in at least three ways: (1) they become reluctant to mount and mate cows because of a weakened physical condition; (2) there is a delay in the age they reach sexual maturity; and (3) there results a degeneration of tissues in the reproductive organs after a prolonged period of underfeeding. This results in a bull becoming sterile.

This brief discussion very definitely indicates that a proper intake of energy, protein, minerals, and vitamins is a must if one is to obtain a high calf crop. Without proper nutrition, cattle do very poorly. Mature cows are able to withstand poorer feed conditions than young heifers. Thus, where there is a choice, one needs to concentrate the best rations on the first and second calf heifers.

2. *Overfeeding of cattle will result in a low calf crop.*

Overfeeding is encountered more often than underfeeding with top quality purebred cattle. Underfeeding is more of a problem with the commercial cattlemen, although some purebred men al-

Harmful effects can also occur from getting bulls too fat. Florida studies have shown that fat bulls become inactive, are more prone to injuries, are reluctant to mate, and are not in condition to be turned out to pasture without proper adjustment in physical condition. Many good quality bulls have been ruined by being turned out to pasture without first being let down in condition which should be done gradually and not at too rapid a pace.

Dairy studies at Tennessee have shown that overfeeding heifers during their early growth period has turned potentially good milkers into poor milkers. This is most likely due to a structural defect which occurs in the mammary gland during the early growing period. This problem needs study with beef cattle since there is a possibility the same thing may occur with them. This means one should avoid, whenever possible, the overfattening of heifers during their early growth period. This means that special management may be needed because the most desirable replacement heifers are usually the ones most likely to grow too fat if overfed.

This brief discussion indicates that overfeeding, to the extent that cows or bulls get excessively fat, for too long a period of time should be avoided as much as possible. For the person who shows cattle, this problem can be helped as follows:

(1) Avoid getting cattle excessively fat for too long a period of time. This problem can also be helped if show judges will continue to discriminate more strongly against cattle which are too fat.

(2) Help educate commercial cattlemen to buy purebred bulls without their having to be fat. This fattening process costs the purebred breeder in getting his bulls ready for sale and then costs the commercial producer to gradually let them down in condition if they are fatter than they should be for breeding purposes. Most commercial men complain about bulls which have been fattened but very few of them will buy bulls, or pay their true value, unless they have been fattened and look in good condition. An education program will help both groups in this matter.

(3) Semen can be obtained from young, outstanding show bulls for storage and possible later use before they get in show shape. This is good insurance against the possibility of the bull becoming a poor breeder after extensive showing.

3. *Beef heifers can be calved at about 2 years of age if the following conditions are met:*

They have sufficient size (at least 600 pounds) when bred at about 15 months of age. Small or undeveloped heifers should not be bred this early since it will result in considerable calving difficulty.

They are fed adequately, but not excessively, up to calving time. If a heifer is well-developed her life-span in the herd is not affected.

They are watched closely at calving since some of them will need help. About 50 per cent of the heifers needed assistance in an Oklahoma study. In general, less difficulty will be obtained if they are bred to somewhat smaller and more refined types of bulls.

They are fed well after calving to provide enough milk for their calf, to insure re-breeding on schedule, and to prevent them from becoming stunted.

Unless these and other conditions of good management are met, one should not breed cattle too early. The net result will be no more, and possibly less, calf production during the lifetime of the cow than if she had been bred later to calve at 30 to 36 months of age. The Oklahoma Station has conducted some excellent work on this problem for those who are interested in more details.

provement in reproduction are the results obtained at the University of Florida Beef Research Unit with a commercial crossbred cow herd. Their reproduction rate in 1953 was 44 per cent. It increased to 82 per cent in 1955, 92 per cent in 1959 and 96 per cent in 1962 (based on a three-month breeding season). At the same time that reproductive performance was being improved, the weaning weight of the calves was also increasing. In 1953, the weaning weights were 350 pounds and increased to 532 pounds in 1962 which was an increase of 182 pounds. The average slaughter grade of the calves also increased from low good to low choice. This increase in productivity occurred by using a strict program of culling non-pregnant females as well as better feeding and management. It illustrates the fact, which has been observed in many Florida herds, that culling for failure to reproduce can be of considerable help in increasing the calf crop. The culling also decreases the stocking rate on pastures and thus indirectly improves the nutritional level of the cattle. In cases where the nutritional level is borderline, the culling of low producers will usually result in a greater production of beef on the ranch with the cattle which are left.

6. *Too high a temperature will adversely affect semen quality in the bull and the estrous cycle in the female.* A high relative humidity will intensify the effects of high temperature. This means that breeding efficiency is decreased if it occurs during the hot months of the year. Purebred cattlemen who need to breed during the summer should keep their animals as cool as is practical in order to increase reproductive rate. Shade, plenty of clean, fresh water, a proper breeding season, and other management procedures can be followed in order to minimize or eliminate any harmful effects from hot weather. Many cattlemen obtain high calf crops in Florida even though high temperatures and humidity occur during the summer. Thus, a hot climate does not necessarily mean low calf crops if the cattle operation is planned and managed properly.

7. *Cattle can tolerate a low level of nutrition at times if it is not too extensive.* Oklahoma studies have shown that a low plane of nutrition during the first and second winters in the life of a beef female retards skeletal development only slightly at maturity, providing recovery occurs on good summer grass. This is possible because a heifer at weaning has already attained about 2/3 to 3/4 of her potential mature height and length of

body. It is best, however, if winter gains can be held to between 0.5 to 1.0 pound per day during the first winter after weaning.

It is not wise to purposely feed cattle at too low a level of nutrition even though some of this weight can be made up later on during the lush pasture season. However, if weight losses are necessary during some winters it is important to make sure that no serious deficiency occurs with protein, minerals and vitamins. If carried too far, the effect of a deficiency of some of these nutrients could be difficult to overcome later on.

8. *The quality of the pasture can influence the calf crop.* Florida studies have shown that grass-clover pastures produced beef at approximately 60 per cent the cost of straight grass pastures. The advantages for the grass-clover pastures included about a 20 per cent higher calf crop (83 versus 64 per cent), slightly heavier calves (427 versus 416 pounds), and about a 30 per cent lower cost per cow yearly ($56 versus $79). Beef production per acre on grass-clover pastures was nearly doubled that on grass pastures (283 versus 146 pounds). Under Florida conditions the use of clover in grass pastures is highly recommended wherever soil and moisture conditions warrant it. We are not sure how much clover may benefit the calf crop in other states or countries. Undoubtedly the use of legumes in other areas is

be a little more lenient in giving cattle another chance because of the large investment in some animals. There is a good correlation, however, to indicate that if a heifer has a poor first calf that she will continue to have the same kind. There are a few exceptions to this, however, and the cattleman needs to take all factors into consideration and decide whether another chance is warranted.

10. *Good management is the key to a successful operation.* Without good management it is difficult to develop a top herd of cattle. A good manager needs to keep abreast of new developments and be alert to what is happening all around him. There is no substitute for hard work, planning ahead, and integrity in developing a quality and reputable herd of cattle. A 100 per cent calf crop does not just happen. It takes a great deal of time and work to develop such a herd. It can be done, yet only a few cattlemen attain this goal. In the meantime, this should be the aim of all who want to develop an outstanding herd of cattle.

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